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WHERE TO LAND ON THE MOON

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SUMMARY

The writer considers the most suitable landing sites on the Moon in the light of personal observations with large telescopes. A chart of such sites is attached and the best spots for actual landings are suggested. The limitation of telescopic observation is stressed and the final decision is shown to be a matter of selection on the part of the crew.

The time is approaching when men will first visit the Moon. Many and varied problems connected with the first lunar journey have received attention from writers; the space-platform, the vehicle, oxidant and fuel and so on, have each come under review, but very little attention has been given to the actual landing sites.

The object of the venture being to effect a landing on the Moon it is evident that not only must the vehicle be provided with means for settling down without undue shock, and in a suitable position for the "take-off," but some attention must be given to find the most suitable landing sites on the surface of our satellite. This is not as simple as it seems, for it presupposes a knowledge of the nature of the lunar surface, not in its broad and general aspect, whether it is mountainous or level, but in the minute features. Before approving the selection of a site it is important to know whether the spot on which the vehicle will settle is a level expanse of rock capable of bearing the weight, or whether a deceptive layer of dust conceals crevasses or other irregularities in the solid surface beneath. If the latter happened to be the case we can visualize one or more of the "landing legs" plunging through the dust and into the cracks with disastrous results to both vehicle and crew.

The selection of landing sites presents two problems. Possible sites must be located in the most advantageous spots for exploration and easily reached from each other and it must be established that within the sites the areas selected for the actual landings are suitable for this somewhat delicate operation.

On the side of the Moon which faces the Earth the southern portion is, in general, mountainous while on the northern portion are found the extensive, and comparatively level plains misnamed "seas." Within the mountainous area the only possible sites are the interiors of certain of the great craterform features or walled-plains. Many of these exhibit rough and disturbed interiors and can be discarded as quite unsuitable for our purpose. The only apparently level expanses in this region are the interiors of Stofler, Schomberger, Pontecoulant and Schickard.

Chart of possible landing Sites on the Moon.

At mean libration the centre of the disc lies near the middle of the small plain known as Sinus Medii, on the southern border of which is the great walled-plain Ptolemy, 90 miles in diameter. Both Sinus Medii and Ptolemy are possible landing sites.

On the north we have such objects as Archimedes, Plato and Meton, with Endymion to the west and Otto Struve to the east. The extensive "seas" are too open to be considered as really suitable sites. Why land on a congealed lava flow miles from any object of interest?

These possible landing sites are shown on the chart and it will be noted that they are well distributed and very approximately equidistant from each other. Those near the apparent edge or limb are suitable for exploration of the Moon's other side.

It remains to inquire whether the surface of these otherwise favourable spots are suitable for landing. This is a matter for direct observation with very large telescopes, which alone are capable of revealing the nature of the ground. We realize that what to us on the Earth seem insignificant irregularities may be formidable hazards to the crew of a spaceship.

Up to the present time large instruments have rarely been employed for lunar observations, the only systematic series of lunar observations being those of the writer and Patrick Moore with the 33-in. and 25-in. refractors at Meudon and Cambridge observatories respectively.

In general the larger the telescope and the better the seeing, the more rough does the Moon's surface appear. Objects which seem nearly or quite smooth in small telescopes are transformed into undulating, much-pitted and fissured expanses in large instruments. Where fissures exist the sharpness of their edges clearly proves that those regions have no covering of dust, the actual rocky surface being exposed.

The existence of large numbers of pits often of considerable depth, is also incompatible with a mantle of dust of sufficient thickness as to approach a levelling up of the surface. Some objects are very bright, others are very dark and the confusion of pits and cracks is more evident in the brighter than in the darker ones. It is not entirely a matter of easier detection of detail in bright objects for some dark spots are altogether rough and warty.

It must be remembered that the smallest object visible in even the largest telescopes must be a couple of hundred yards across, that is of equal size to a landing site. In other words a landing site would appear as a mere dot in the finest instruments. In examining various objects on the Moon with a view to establishing their suitability as landing sites I have looked for such bright dots and where one has been seen have assumed that it indicates an uneven and unsuitable area.

In every object critically examined such indications have been detected, separated by expanses which seem perfectly smooth but which, in all probability, actually contain pits and cracks too small for telescope detection. *The entire surface of the Moon, even in the apparently perfectly smooth regions, is probably so rough and uneven as to make landing a matter of selectivity on the part of space-travellers.* No evidence has been found for extensive dust deposits, the apparent surface being the true and solid crust of the Moon.

From a consideration of the translucent appearance of some of the lighter regions, notably that of the Palus Somnii (X on the chart), and the remarkable apparent variations in certain areas during the course of a lunar day, it is very possible that a good deal of the surface layer is itself of a brittle nature, with numerous cavities below the surface. Although probably only a few inches across and a few inches below the surface, the presence of great numbers of such hollows renders the surface incapable of sustaining any appreciable weight and therefore unsuitable and unsafe for landings.

The conclusion seems to be that the most suitable landing sites are the darker portions of the objects charted which are themselves remarkably smooth in comparison with the majority of lunar formations. A safe landing can probably be effected on a dark area between adjacent brighter spots, but the actual degree of smoothness can only be determined when within a few miles of the surface.

ARMSTRONG SIDDELEY MOTORS have a vacancy in their Rocket Engine Design Office for a Senior Design Draughtsman with HNC or higher qualification, aged 25 to 35. Experience in light mechanisms, such as gearboxes, hydraulic valves and pumps etc., or in aero engine installations or structures would be an advantage. Apply to Personnel Manager, Reference EGDA3, Armstrong Siddeley Motors, Coventry.

NAVIGATION WITHOUT GRAVITY

By J. G. Porter, Ph.D., B.Sc., F.R.A.S.

(*A paper read to the British Interplanetary Society in London on November* 7, 1953)

SUMMARY

Small errors in the initial speed and direction of a spaceship are discussed in relation to the large errors which these cause in the size and shape of the orbit. It is shown that some form of navigation is essential in space travel, and some simple methods are suggested. The difficulties of correcting the course are also described.

There is a good deal more in navigation than the simple finding of position, and I would commend to your attention the definition "Navigation is the science of getting to the right place along the right route at the right time." This seems to me an admirable statement, with particular application to navigation in space, and it will be noticed that it poses three questions for the space navigator:—

(*a*) Where am I?
(*b*) Am I going the right way?
(*c*) If not, what am I going to do about it?

Now the answer to the first question is found in terrestrial navigation by measuring two angles, which are usually the elevations of two celestial objects above the observer's horizon. The presence of a horizon (or of a bubble in the bubble sextant) implies the presence of gravity, but out in space there will no no such convenient lines of reference. Bubbles, like plumb-lines, do not exist where there is no gravity; how, then, do we navigate without gravity? In theory, of course, three position lines will be sufficient to determine a position in space, but before dealing with the various methods that might be adopted, I would like to emphasize one point that has not been sufficiently stressed. This is the simple fact that in a spaceship, whether manned or not, *navigation is essential* if the orbit is to be accurately defined.

Let me deal with this question of accuracy first. I shall not take a special orbit, because I do not believe for one moment that space travellers will have to wait for the exact moment when the ship can travel from the perihelion of one planetary orbit to the aphelion of another. They will just go! Nor do these simple calculations of times and velocities based on elliptical orbits do more than give a rough approximation to the truth; as I have pointed out before, the problem is a three-body problem, and there is no general solution. The figures that I am going to quote are intended merely to indicate the sort of errors that may arise if the spaceship sets out with the wrong speed or at the wrong angle.

Let us consider a trip to Mars. The Earth is assumed to be moving in a circular orbit of unit radius, and Mars, at the end of the journey, is assumed to be 5/3 units from the Sun. The ellipse in which the spaceship will travel therefore has a semi-major axis $a = 4/3$, and since the perihelion distance $a\ (1 - e)$ is 1, the eccentricity $e = 0{\cdot}25$. If the Earth's velocity be taken as unity, then the velocity of the ship at the start is given by

$$V^2 = 2 - \frac{1}{a} = 1\tfrac{1}{4}$$

so that $V = 1{\cdot}118$. In the same way, the velocity at aphelion will be 0·671, which is about 0·07 units (1·2 miles/sec.) slower than Mars. The time to reach Mars is easily found to be 281 days. We will ignore the actual navigation in the neighbourhood of a planet, and consider that this pilotage is only necessary within a distance of 50,000 miles—in other words, we shall be quite content if we can navigate the ship to within that distance (say 0·0005 unit) of Mars.

Consider first the effects of an error in the initial velocity. From

$$V^2 = 2 - \frac{1}{a} \quad \text{we derive} \quad \mathrm{d}a = 2a^2V.\mathrm{d}V$$

and if we put Q for the distance of Mars from the Sun, then

$$Q = 2a - 1 \quad \text{and} \quad \frac{\mathrm{d}Q}{Q} = \frac{2\,\mathrm{d}a}{2a-1} = 4a \cdot \frac{\mathrm{d}V}{V}$$

or, in words, the relative error in the aphelion distance is $4a$ times the relative error in the velocity. As we might expect, the error is greatest with the greatest distances from the Sun, and in this particular case, since we wish to make the relative error 0·0005 units in 5/3 units, $\frac{\mathrm{d}V}{V} = 0.000056$—or, say, one part in 18,000. This implies that the initial velocity must be controlled to within 0·001 mile/sec., which is definitely beyond our present capabilities. The implications are obvious, and it is clearly necessary to have some form of navigation. These conclusions are amplified in Table I, which shows the changes which take place in the orbit with varying initial speeds. It will be seen that as the speed increases, the orbit

TABLE I

EFFECT OF ERROR IN INITIAL VELOCITY

V	a	e	Aphelion distance	Time to aphelion (days)	Time to Martian orbit (days)
1·09	1·232	0·188	1·463	250	—
1·10	1·266	0·210	1·532	260	—
1·11	1·302	0·232	1·605	271	—
1·12	1·341	0·254	1·682	284	250
1·13	1·383	0·277	1·766	297	210
1·14	1·428	0·300	1·856	312	190
1·15	1·476	0·322	1·952	327	176

not only grows larger, but its eccentricity increases. In the first three cases, the orbit does not reach out to the Martian orbit, but the other four take less than the standard 281 days to reach this distance. The reduced time, however, is of little advantage, since the angles of intersection of the orbits become somewhat inconvenient.

The examples given so far have assumed that the start of the journey has been made at the perihelion of the orbit, and this implies that the direction of

take-off is perpendicular to the line earth-sun. What will happen if the angle is not exactly a right-angle? This is a matter which seems to have been overlooked, yet errors of this kind are in some respects more serious than those caused by erroneous velocities. Suppose the radius vector R (= 1) which joins the Earth to the Sun to make an angle s with the forward direction of motion of the spaceship. Then R forms an angle v (the true anomaly) with the major axis, and these angles are related by the expressions:—

$$p \cot s = R e \sin v.$$
$$p - R = R e \cos v$$

where $p = a(1 - e^2)$. From these equations it may be seen that

$$dv = \frac{p}{p-1} \operatorname{cosec}^2 s \cdot ds$$

and in the special case of $s = 90°$, $p = 5/4$, the error in v is given by $dv = 5\,ds$. It is clear that the error dv at perihelion causes an exactly equal error at aphelion, and an error of 0·0005 unit at a distance of 5/3 unit corresponds to an angular error of a minute of arc. Thus the angle of take-off must be 90° *within a fifth of a minute of arc.* This is, perhaps, making the worst of the situation, for it is certainly true that an error greater than this would not be a serious matter *provided that Mars overtakes the ship.* But this is not necessarily the case, because the effect of setting off at the wrong angle and the right speed is to change the shape and size of the orbit as well as its orientation in space. This is illustrated in Table II, which gives, for various angles s, the eccentricity, aphelion distance and true anomaly in the orbit. The distance of the spaceship from the Sun after

TABLE II

EFFECT OF ERROR IN INITIAL ANGLE

s	e	Aphelion distance	dv	Distance at 180°	Time to Martian orbit (days)	Time for 180° (days)
°			°			
86	0·259	1·678	+ 19·6	1·645	233	312
87	0·255	1·673	14·8	1·654	245	304
88	0·252	1·669	10·0	1·661	257	296
89	0·251	1·667	+ 5·0	1·665	269	288
90	0·250	1·667	0·0	1·667	281	281
91	0·251	1·667	− 5·0	1·665	278	274
92	0·252	1·669	10·0	1·661	275	266
93	0·255	1·673	14·8	1·654	272	258
94	0·259	1·678	− 19·6	1·645	269	250

completing 180° in longitude is also given, together with the time to this point, and the time to the Martian orbit. It will be noticed that although the orbit having $s = 90°$ just reaches the Martian orbit, the others are all more elongated ellipses, and they cut the path of Mars in two places—but always at the wrong time and place! An error of half a day would not matter much (the relative speed of Mars with reference to the ship being of the order of 1 mi/sec.) but to arrive some days late would be rather worse than missing the last bus home.

We may conclude, therefore, that the initial velocity and angle must be determined to an impossibly high order of accuracy, so that navigation, which must include correction of speed and course, is a necessity.

Now the course is not in reality an undisturbed ellipse, since the spaceship will be subject to perturbations by all the other bodies in the solar system. These perturbations may be computed beforehand by a system of mechanical integration which I have described on another occasion.* The path which the ship is following at any instant requires six quantities to define it completely, so that six single or three double integrations are necessary. A large-scale electronic computer can calculate the perturbations by all the planets for any one date in a few seconds, so that the course, or any number of possible courses, can be worked out in advance. Such calculations are usually performed in terms of rectangular co-ordinates, but it does not follow that these are necessarily the most convenient. Thus the undisturbed orbit of the spaceship must lie in a plane about the Sun, and the position at any time *in that plane* may be defined by a longitude in the orbit and a distance from the Sun. In one particular method of dealing with special perturbations—that due to Hansen—the changes in these two measures are computed, together with that in "latitude" (measured perpendicular to the original plane), and this would seem to be admirably suited to the needs of the space navigator. Since the highest accuracy is unnecessary, the method could be made rapid and entirely serviceable. It is to be hoped that before long some attempt will be made to illustrate the method, if only to show how necessary it is to include perturbations in any of this work on orbits. Such computations would not be very arduous since, as has already been remarked, an accuracy of a minute of arc is sufficient, and five-figure working would give all the results that could be desired.

The mere determination of position in space (as distinct from a knowledge of position within a given orbit) is not, to my mind, a very important part of space navigation. It should, however, be possible to obtain reasonably accurate positions at any given time by means of three position lines. Since the relative positions of the stars in the sky are the same (to the required accuracy) in any part of the solar system, the stars alone cannot be used for determining position. The only base lines available to the navigator are those joining the ship to the Sun or planets, and the angles between these lines would afford a good measure of the longitude of the ship.† The latitude would best be obtained from the angular elongation from the Sun of stars near the pole. Incidentally, it must be emphasized that since the base-lines employed are all moving lines in space, an accurate knowledge of time is a very necessary requisite in space. What would happen, for instance, if there were a failure of the time-recording system on the ship? This is an interesting problem, to which there would appear to be no simple answer.

The measurement of the direction in which the ship is travelling, and of its speed at any given moment, would be of much greater value than a measurement of position. If, for example, there were some method of measuring the angle which I have called *s*, then most of the difficulties of navigation would clearly

* *J.B.I.S.*, **11** (5), 205, September, 1952.
†*cf.* Atkinson, *J. Inst. Navigation*, **3**, 365, 1950.

have been overcome. The more pressing need, however, is for a method of measuring the velocity. The only suggested methods are to make use of the Doppler effect of the displacement of spectral lines (and this includes the change of frequency of a radio signal) or to measure the aberrational displacement of stars in suitable parts of the sky. Both methods depend essentially on the ratio of the velocity of the observer to the velocity of light, and it is not easy to see how the accuracy required can be obtained by these methods. It is true that the Doppler effect is doubled by reflection, so that this method will be of great value in the actual pilotage of a ship near a planet, where the use of radar methods is possible.

It becomes clear that the only readily observable body in the universe as far as the navigator is concerned is the Sun, and it behoves him to make use of the fact. The solution that immediately suggests itself is to photograph the Sun at regular intervals, for it would be quite possible, in the clear emptiness of space, to obtain photographs of the Sun against its background of stars. The same method has already been adopted on Earth for the accurate determination of the Moon's position, filters being used to decrease the amount of light coming from the Moon itself. There is no reason why the same method should not be equally successful with the Sun, as seen in empty space, and the photographs so obtained would give all the required information. The diameter of the Sun is inversely proportional to its distance, and the longitude is readily determined by the angular displacement of the Sun from suitable identified stars. Even this measurement is not entirely necessary, since the motion of a ship must lie in a plane (apart from perturbations) so that all the images of the Sun should lie on a straight line, the actual displacement of the Sun's image during any one day giving an immediate measure of the daily change in longitude. This quantity can readily be determined beforehand for any particular orbit and time. Hence if the ship is on its right course, the photographs will show an image of the Sun of the right size, displaced the correct amount from the previous image. There is clearly no reason why the process should not be made entirely automatic; indeed one can go farther and make use of other related quantities. Thus the amount of light (or heat) received from the Sun is inversely proportional to the square of the distance. Since for any given orbit (ignoring perturbations) the radius vector sweeps out equal areas in equal times, we have $r^2 \cdot dv/dt$ a constant, and this constant can also be determined in advance. This leads at once to the useful fact that the amount of light (or heat) received from the Sun is proportional to dv/dt, that is, to the displacement of the Sun's image on the photographs. Thus it would be possible to combine this simple measurement with Hansen's method of computing perturbations, and correct the calculation accordingly. The apparatus could be adjusted to record any variations from pre-determined values, and in this way the ship could be maintained on the right course. The assumption here is that the Sun radiates light (or heat) continuously and without variation, and some preliminary research would be necessary to determine this point, although I have no doubt that some method could be found of overcoming any small variations. The method is, at any rate, too simple to be lightly disregarded.

Yet however simple the method of determining a "fix" in space, the difficulty

still remains of altering the motion of the ship to restore it to the correct orbit. It is all too often assumed that the use of the auxiliary jets will enable the ship to be steered in any desired direction, but this is far too optimistic a view of the matter. Any force acting on a body in space will cause an acceleration, but the effect on the ship can only be determined by combining this acceleration with that already present, namely with the acceleration which is directed towards the Sun. In other words, an acceleration imposed in any particular direction will not, in general, cause motion in that direction. The effect is far more complex, and nearly always causes an alteration to more than one of the six elements of the orbit. The full details of the effect of such forces on a body describing an orbit about the Sun are described in detail in textbooks of celestial mechanics,* and here it is proposed only to deal with one or two points of interest.

It is usual to resolve a perturbative force into three components at right angles, and for our purpose we may choose one component to be tangential to the orbit, the positive direction being in the direction of motion; a second (normal) component at right-angles to the tangent in the plane of the orbit, and directed positively to the centre of the orbit; and a third (orthogonal) component at right-angles to the other two, and positive if directed to the pole of the orbit. Now the effect of a positive tangential force is to increase the speed of the ship, and this not only increases the size of the orbit, but will also alter the eccentricity. The latter effect is greatest at perihelion, and exactly what this means has already been shown in Table I. But at any part of the orbit the effect of altering the speed will be to force the ship into another orbit. This suggests that a certain amount of steering can be carried out in this way, but in general it will clearly be best to use such methods only when comparatively close to a planet, where the changes in the circum-solar orbit are of little account.

The normal component also alters the eccentricity of the orbit, and in addition causes a rotation of the whole orbit in space. Here again, it is not possible to apply a simple change of speed and direction. All that can be done is to change from one orbit to another, and therefore *two* changes are always necessary—one to change from the erroneous orbit into another which will carry the ship to the correct place at a given time, and then a second change to the correct direction and speed in the true orbit. Such changes could only be brought about by the action of jets, the force and direction of which would have to be computed on the spot. The complexity of this problem is not pleasant to contemplate.

We turn, therefore, to a more simple problem, but one which has also been overlooked by most writers. The planet Mars revolves about the Sun in an orbit which is inclined 1° 51′ to the ecliptic. This means that the planet may reach a distance of 5 million miles "above" or "below" the Earth's orbit, and we wish to make our ship reach this position, or within 50,000 miles of it. It is useless to set off in an inclined path, because that path will intersect the Earth's orbit again after traversing 180° of longitude. The actual direction of travel must be altered somewhere en route—where is the best place? Now the

* *See*, for example, Moulton, *Celestial Mechanics*, Macmillan, London, 1902.

only component which affects the inclination of the path is the orthogonal one, and the effect is a maximum at the nodes. This clearly gives us the answer to our question—the ship should continue in its initial orbit until it reaches a longitude corresponding to the node of the Martian orbit. At this point the jets may be arranged to cause an orthogonal force to act, thus increasing the inclination without otherwise altering the orbit.

This appears to be the only simple case of the use of the auxiliary jets—yet is it as simple as it appears? The difficulty of determining the direction in which the ship is travelling has already been referred to, and this clearly causes further difficulty in determining the direction in which the jets are to be fired. But this is an engineering problem, for a reliable gyroscope could be used to define the pole of the original orbit, and this, with the line joining the ship to the Sun, would give a suitable frame of reference. The difficulties, in fact, seem to me to be mainly those of the engineer—I am quite sure that the problems of navigation in space will not prove to be as difficult as they may appear to be at present.

A MINIMUM ORBITAL INSTRUMENTED SATELLITE—NOW*

By Professor S. F. Singer

SUMMARY

Within a few years our technology of building large rockets will have advanced to the stage where we can actually put a very small body into an orbit around the Earth. The MOUSE (Minimum Orbital Unmanned Satellite, Earth) would weigh about 100 lb.; we should be prepared to have it orbit for only a short time and then lose it.

This project could pay its own way. With only a small payload of scientific instruments we could obtain information on solar radiations of immense importance to radio communication and to the problem of weather.

What Constitutes a Minimum Satellite Vehicle?

Before we attack the technical problems of propulsion, control and instrumentation of such a project, we must first ask ourselves this question: What really constitutes a minimum satellite vehicle? Clearly, the absolute minimum would be a slug which is ejected with the orbital velocity at some altitude above about 200 miles in the appropriate direction so that it can describe an orbit about the Earth. This inert and passive body would weigh only a few pounds and might carry a piece of reflecting material so that it could be observed. But what can such a project do for us? If this body deviates from its orbit, we have no means of restoring it to its proper position; it only tells us that we have made a mistake in the planning and control of the operation. It is significant, however, that with the addition of a few more pounds of the right type of equipment this small body can become so useful scientifically and economically as to constitute a worthwhile, paying proposition. Thus, a satellite vehicle weighing only of the order of 100 pounds could contain scientific instruments to carry out measurements of far-reaching importance. As we shall see below, this low weight makes the propulsion problem very simple indeed; in fact it looks as if

* *Presented at the Fourth International Astronautical Congress, Zurich, 1953.*

one can almost do the job with available large rockets as the primary stage of the multi-step vehicle.

The next problem to consider would be the time such a vehicle should spend in an orbit, since this determines to a large extent the control problem. I would suggest here that the initial orbital vehicles used for astrophysical research would give much valuable data even after only a few hours of operation, i.e. after a few orbits around the Earth. It is therefore not necessary for the body to continue in its orbit for an indefinite period of time. It is therefore not necessary, and this is quite important, to make provisions for correcting the orbit of the body once it begins to deviate. This single feature leads to a great simplification in the design of the final stage.

We are therefore left with a satellite vehicle which we have named the MOUSE (Minimum Orbital Unmanned Satellite Earth). This name was proposed in collaboration with Mr. A. C. Clarke and Mr. A. V. Cleaver.

It might be useful at this stage to indicate how close we are to the goal which has just been stated, at any rate in the propulsion end. If we examine study proposals for Earth satellite rockets, for example a recent B.I.S. paper,* we can deduce that a final stage with a total weight of 50 kilograms requires an all-up weight of 16,000 kg. and a thrust of approximately 30,000 kg. in other words not much more than the thrust of the present V2 rocket. Thus it would seem that putting a 100-lb. vehicle, such as the MOUSE, into an orbit is a goal which is not very far away. It is clear that with the limited objectives of the MOUSE all the control functions could be relegated to the first and second lifting stage where the weight requirements are not severe and where quite elaborate control equipment can therefore be used. This will, of course, relieve the final stage from carrying such equipment and considerably reduces the total weight of the last stage. As far as the utilization of the payload of the last stage is concerned, we can talk about this subject with some degree of certainty since we have behind us the experience of high altitude rocket research where instruments have to be built within the limitations of very small weight and space and also with very high reliability. Much of the experience gained in high altitude rocket experiments will be directly applicable to the instrumentation problems of the Earth satellite as will be pointed out later. Certainly now is the time to begin planning such a satellite instrumentation since it appears that before too long such opportunities for doing research may become available to us.

It seems fair also to state that the successful operation of an orbital rocket such as the MOUSE will have extremely important consequences for our studies and knowledge of astrophysics, in particular of solar physics and of the solar radiations. Such studies in turn, would have practical consequences which affect our everyday life. Certainly these results would be of the greatest importance for radio communication and may even enable us to deal in a more scientific way with weather and weather predictions.

These, I think, are conservative and sober claims for the usefulness and worthwhileness of the MOUSE. I feel very strongly that one must speak up

* "Minimum Satellite Vehicles," K. W. Gatland, A. M. Kunesch and A. E. Dixon, *J.B.I.S.*, **10**, 287–294, 1951.

in this field for the conservative point of view, since over-optimism, and above all, any exaggerated claims for an orbital vehicle may have detracting effects on the realization of such a project. I am rather dubious about claims concerning the so-called military advantages of an orbital vehicle, such as reconnaissance and pin-point bombing. Being presented with an exaggerated picture of the size of the effort and of its cost many people may become sceptical of even a minimum satellite. Certainly, however, the way to get started on larger space-stations is by demonstrating the feasibility of a minimum satellite.

I would summarize my feelings as follows: Within a few years the means will be available to us for putting a vehicle, such as the MOUSE, into an orbit. Whether we can use these means to carry out an orbital project will depend on how well we can justify the usefulness of such a vehicle. It behoves us, therefore, to think through very clearly the benefits we can derive from studies carried out in such a satellite vehicle.

Problems of the Solar Radiations

Before we consider in more detail a possible set of instrumentation and the types of observation to be made in the satellite, it might be useful to review first certain features of the solar atmosphere and of solar phenomena which affect the Earth. Most of the energy which reaches us from the sun arrives in the form of radiation in the visible region of the electromagnetic spectrum. However, of vital importance to us is the radiation in the ultraviolet, invisible part of the spectrum. The ultraviolet radiation from the Sun produces the ionized layers in the atmosphere (ionosphere) which are so important for long-distance radio communication, and is also responsible for numerous photochemical reactions in the atmosphere, such as the production of ozone. The ozone layer not only protects life on the Earth from the powerful ultraviolet radiation but retains within the atmosphere the heat delivered to the Earth by the Sun. Changes in the ozone layer are definitely connected with weather in the lower atmosphere.

Although the Sun appears to be a quiet and stable light-emitting star, this situation is not true if we consider the ultraviolet radiation from the Sun. This radiation, which originates in the solar atmosphere, is connected with the dynamic and disturbed conditions which may exist in the solar atmosphere; its emission may vary by many orders of magnitude during periods of solar excitation. Typical phenomena which occur on the Sun and which have pronounced effects on the Earth are some of the following. Often one observes near sunspots small bright filaments. Sometimes these areas begin to grow and their brightness may go up considerably as a solar flare develops. We know that connected with this increase in brightness of a solar flare is a vastly increased emission in the ultraviolet region. Its immediate effect is to produce a sudden ionospheric disturbance; larger flares may cause radio fadeouts. Following some solar flares one observes some hours later the onset of a severe disturbance in the Earth's magnetic field (magnetic storm) accompanied by large displays of aurora near the north and south polar regions. The effects of these magnetic storms may sometimes be very severe; they may burn out telephone lines and cables, and thus interrupt even wire communication, while auroræ in the polar

regions generally have deterimental effects on radio communication. The phenomena of magnetic storms and auroræ are generally explained in terms of a stream of ionized gas (corpuscular radiation) which is emitted from the Sun at the time of the flare and reaches the Earth some hours later.

Sometimes, associated with solar flares we find the occurrence of a sudden increase all over the earth in the intensity of the cosmic radiation. This phenomenon is not at all well understood, since it seems that only few flares lead to such cosmic ray increases. It would be of the greatest physical interest to discover by what process the Sun is capable of accelerating nuclear particles to the extremely high energies which the primary cosmic radiation possesses.

A very vital question and a most important one from the economic point of view is the effect of solar conditions on the Earth's weather. It is held by some meteorologists that radiations from the Sun, either ultraviolet or corpuscular, may serve to trigger weather processes in the lower atmosphere and thereby initiate weather conditions on the Earth which then travel over the continents and oceans. In order to confirm this speculation, however, it would be necessary to obtain full and continuous information on all of the radiation emitted from the Sun and correlate and connect it with our observations of weather on the Earth. Should we establish such a connection, it may then become possible for us to determine weather conditions on a really long-range basis. The economic value of this possibility is too evident to be elaborated here.

Application of the Satellite to the Study of the Sun

Neither the ultraviolet nor the corpuscular radiation from the Sun can be observed directly at sea level since the atmosphere is not transparent to them. Instead, they must be inferred from other less direct observations. It is at this stage therefore where the full advantages of a rocket become apparent. However, none of the present high altitude rockets can spend more than about 5 min. above the appreciable atmosphere; they are therefore not suited for continuous observations and for the study of the infrequent phenomena just described.

We may now proceed to discuss the instrumentation which we must put into an Earth satellite like the MOUSE in order to carry out observations and measurements of the changing solar conditions on a continuous basis. As we shall see, only a few pounds of instrumentation would enable us to obtain a rather detailed picture of the conditions existing during solar disturbances measured in terms of the emission of solar ultraviolet, of solar corpuscular streams, and possibly cosmic rays.

In the measurement of solar ultraviolet and X-rays the problem would be to carry on continuous measurements of intensities in different wavelength regions and to record it as a function of time. This would then make possible correlations with observations at sea level of the visible Sun and with effects produced by the solar ultraviolet and X-rays in the Earth's atmosphere. Perhaps the most fruitful instrument for the continuous detection of the radiation is the ultraviolet and X-ray photon counter which has been used by the Naval Research Laboratory in various rocket experiments. These photon Geiger counters are specially constructed to be sensitive only to photons within

certain wavelength intervals. Some can be made to be sensitive to X-rays only. In this way it is possible to monitor the intensity in the particularly interesting regions of the solar spectum, for example, in the important emitting region of the hydrogen Lyman-alpha line (1215 Å). The circuits used with these counters are quite simple. The whole arrangement should weigh no more than about 5 lb. For the photon work it is necessary to be above at least the lower layer of the ionosphere, i.e. 150 kilometers.

For the study of the primary cosmic radiation it is convenient to make use of their deflection in the Earth's magnetic field which therefore acts as a momentum analyser. The charged particles of the primary radiation are affected by the Earth's field in such a way that low energy particles do not arrive in the region of the equator; they can, however, arrive near the polar regions. By measuring the cosmic ray intensity as a function of latitude, it is possible to obtain the distribution of energy in the primary cosmic radiation. Thus by directing the path of the satellite along the meridian, one obtains the energy spectrum of the primary radiation four times during every two-hour orbit. Such measurements can be of paramount importance in the interpretation of cosmic ray variations, particularly those produced by solar events. During increases of the cosmic radiation one would like to know whether the existing cosmic rays are being accelerated or whether the Sun is actually producing additional cosmic rays. The present experimental evidence based on sea-level observations is not at all decisive between these two possibilities and any direct information on what happens to the primary cosmic rays would be of the greatest importance. It is necessary, however, to deal with the primary radiation directly and to determine any change in its energy spectrum in order to gain information about what is affecting the primary cosmic radiation.

The instrumentation necessary to do these measurements consists of Geiger counters and is quite simple. Judging from earlier work in "Aerobee" rockets, an instrumentation weighing about 5 lb. should again be sufficient to obtain the necessary information.

In order to detect the existence of corpuscular streams coming from the Sun, one may apply a novel method for their detection based on magnetic measurements. This corpuscular stream which consists of a rarified ionized gas may or may not carry a magnetic field. Regardless of this, when it approaches the Earth's magnetic field it will "squeeze in" the lines of force. This effect should be detectable by means of sensitive magnetometers, such as those which have been used in previous rocket experiments to measure magnetic field changes in the ionosphere. In fact, it seems very likely that motions of ionized gas in the outer regions of the Earth's magnetic field affect its strength and that these are transmitted to some extent through the ionosphere and thus cause magnetic field variations at sea level. However, we also know that currents in the ionosphere itself may produce magnetic variations at sea level. In order to distinguish between these two agencies producing magnetic field variations, one should consider what is observed by a magnetometer located above the ionosphere and compare this with magnetic observations below the ionosphere.

Clearly, both will see variations produced by outside influences, such as ionized gases moving into the Earth's field, in the same way. However,

they will view magnetic variations produced by ionospheric currents in the opposite direction. Thus, comparison of the two magnetometer informations makes possible a unique separation between ionospheric effects and cosmic effects on the Earth's field. A magnetometer above the ionosphere would therefore be a sensitive detector of the motions of ionized gases in the vicinity of the Earth. It would be a particularly valuable and quite a simple means of recording streams of ionized gas coming from the Sun. From previous experience in rockets one would judge the weight of this instrumentation to be of the order of 15 lb.

Conclusion

It becomes evident that with only a few pounds of payload in the form of instruments a satellite rocket can solve important problems of solar physics which, in the future, may have practical consequences of great importance for us. A project of this type becomes therefore a worthwhile proposition, able to "pay its own way."

Many of the present proposals for the use of satellites are not at all realistic, especially some of the military uses; they demand too much in the way of size and in complexity. In order to progress, therefore, we must be ready to justify a project even if the satellite is very small and minimal. Only in this way can we make use of the opportunities which the next few years may offer for such a project. If we can plan for this minimum satellite, the MOUSE, we may be launching it sooner than we now think possible.

INTERPLANETARY COPYRIGHT

By H. E. Ross

Since most things now have a "space angle," it is only natural that the question of extra-terrestrial copyright should crop up. True, no-one has yet suggested that the various interplanetary plays and serials which are being pumped into the ether are being pirated by the Venusian and Martian radio networks, but if so, that would constitute an infringement of copyright which could not be overlooked. This possibility is not mentioned in a "cosmocomical" contribution to the January, 1953 *Bulletin* of the American Library Association, but the writer, Donald F. Reine, does present a number of other copyright problems that might arise when astronautics has got under way. Says he, "We feel that, in keeping with the glorious traditions of the Copyright Office, we should make every effort to solve most of these problems now, so that the pilot of the first rocket to the Moon can make his flight with a mind free of anxiety, and with the knowledge that the Service Division, the Examining Division, the Cataloguing Division, and the Reference Division, are all solidly behind him. And we do mean behind."

Getting down to cases, Mr. Reine begins by considering the applicability of the Copyright Law to an American lunar colony. "Assuming," says he, "some poet stationed there prints and distributes a book throughout the American colony, the question arises as to whether it can be registered, and in what class.

The majority feels that it should be accepted under the conditions which apply to the territories and possessions of the United States, but the minority holds that only an *ad interim* registration is possible, since the Moon is most certainly *outside* the United States. Several have expressed merely their hopes of retiring before the problem arose."

Inhabited planets, such as perhaps Mars and Venus, present more difficult problems owing to the possibility that intelligent life may occur in strange forms and speak and write in many different languages. Foreseeing this, Mr. Reine asks: "If they are friendly and produce objects similar to the present classes of registerable articles, will we establish copyright relations with them and register these items? If we do, the recruitment of native personnel of these planets to handle the applications in the Copyright Office seems a necessity, at least until the languages are well known on Earth. While it is highly desirable to bring all this new material into the collections of the Library of Congress, some present members of the staff have gone on record to the effect that they will not work with anything green in colour, scaly in texture, or over 15 ft. tall. As segregation has never been sanctioned here, it is felt that this problem should be brought to the attention of the Employee Relations Officer."

Physiological differences present even greater problems than those of aspect. Says Mr. Reine, "It is possible some Martians or Venusians may have more than one head. In this case, would we register the work of one of these creatures as that of a single author, or would the name of each head be set down as co-author?"

Leaving this siamesian question unanswered, Mr. Reine sets out for the stars. Here he finds problems of a different nature. For example, that the 28-year term of copyright will cause great hardship to those authors domiciled at the other end of the Galaxy. He points out that "A book published on Aldebaran and dispatched immediately to the Copyright Office would reach here in its 36th year, too late to register. The rule deduced from this is that the term of copyright must be increased in proportion to distance from the Copyright Office. If this is not done there may be retaliatory measures and the breaking off of Copyright relations, resulting in the works of American authors being unregisterable on Sirius, Canis Major, 23 Cygni, and other far-flung places. It will not sit well with the American publishing industry to know that its best sellers are in the public domain throughout most of the Milky Way."

Mr. Reine jocularly concludes that we may have to leave these matters to the deliberations of the first Intergalactic Copyright Convention, but he has something to say about the Office reorganization necessitated by the tremendous amount of new material the planets and stars will furnish, the present system of examining being inadequate for such a load. Says he, "it has been suggested that we install a giant thinking machine, possibly occupying the entire Annex, into whose circuits we build the Copyright Law and all decisions made in the Courts and in the Office. (It is estimated that 20,000,000,000,000,000,000 vacuum tubes should suffice.) Applications will be submitted on punched cards which will be fed into the machine and either accepted or rejected immediately. Doubtful cases which now require five or six weeks deliberation can be cleared in one-millionth of a second, thus eliminating our backlog and our Friday

afternoon reports concerning them. This alone will save 27,375,549 man-hours per year."

"Since persons having a knowledge of cybernetics, nuclear physics, general semantics, non-Euclidian geometry, and electronics are not usually available in the labour market, it is expected that we will use the present staff. Mistakes will be made at first, but this is not unusual in any large-scale changeover.

"One suggestion for handling the mass of statistics produced by these operations is that we hire 'calculating wizards,' those strange persons who can perform tremendous mathematical calculations in their heads. It is felt that the fact that these wizards are usually idiots outside their ability to calculate should not be grounds for barring them from employment, since the Examining Division has never discriminated in this way in the past."

Speaking for ourselves, we can only hope that these extracts from Mr. Reine's article does not constitute an infringement of copyright, otherwise we shall be forced to cross space sooner than intended !

FLYING SAUCERS

The following information is contained in a "Fact Sheet" issued by the U.S. Department of Defence as a result of Air Force investigations of unusual aerial phenomena:—

"The Air Force first took official notice of reports of so-called 'flying saucers' in the Fall of 1947, when reports from the public indicated that the matter might involve air defence of the United States. The Air Material Command, Wright-Patterson Air Force Base, Dayton, Ohio, was directed to set up a project to collect and evaluate all available facts concerning 'flying saucer' sightings.

The Air Material Command, in turn, obtained the services of civilian and military astronomers, psychologists, electronics specialists, meteorologists, aeronautical engineers, and physicists to aid in study and research.

Two years later, on December 27, 1949, after 375 reported sightings had been investigated, the Air Force announced the findings of the 'flying saucer' project.

The majority of the sightings could be accounted for as misinterpretations of conventional objects, such as balloons and aircraft. Others could be explained as meteorological phenomena or light reflections from crystallized particles in the upper atmosphere. Some were determined to be hoaxes. However, there still remained a few unexplained sightings.

The investigation of unknown aerial phenomena was then transferred to the Air Technical Intelligence Centre at Wright-Patterson Air Force Base as a continuing project.

During 1952, the bumper year for 'saucer' sightings, 1,700 reports were received by the Air Force, of which 70 per cent. came from civilian sources. Approximately 20 per cent. of the sightings were unexplainable on the basis of information received.

During 1953, by mid-year, only 250 reports had been received, of which

nearly 50 per cent. came from military sources. The number of unexplainable sightings dropped to 10 per cent.

The drop in unexplained sightings is largely due to the increased accuracy and the completeness of reports being received. To be of value, a report should include such basic data as size, shape, composition, speed, altitude, direction, and the manoeuvre pattern of the objects. Without such information, it is almost impossible to establish the identity of the object sighted. In addition, a recent study has shown a direct correlation between the number of sightings reported and the publicity given to 'saucers' by the nation's press.

In order to overcome this lack of basic data, and to standardize all reports, a detailed questionnaire was prepared by the Air Technical Intelligence Centre and is now submitted to each person reporting an unidentified aerial object. It is felt that the information thus obtained will lower still more the number of unexplained sightings.

The majority of all reported sightings have been found to involve either man-made objects such as aircraft or balloons, or known phenomena such as meteors and planets.

Present-day jet aircraft, flying at great speeds and high altitudes, are often mistaken for unknown objects by the untrained observer. Sunlight reflections from the polished surfaces of aircraft can be seen plainly even when the aircraft itself is too distant to be visible.

Weather balloons also account for a substantial number of sightings. These balloons, sent to altitudes of 40,000 ft. and higher, are launched from virtually every airfield in the country. They are made of rubber or polyethylene, swell as they gain altitude, have very good reflective qualities, carry small lights when launched after dark, and can be seen at very high altitudes.

In addition to the ordinary weather balloon, huge 90-ft. balloons, which sometimes drift from coast to coast, are used for upper air research. These balloons also have a highly reflective surface and are visible at extreme altitudes.

Frequently, unusually bright meteors and planets will cause a flurry of reports, sometimes from relatively experienced observers. At certain times of the year, Venus, for instance, is low on the horizon and will appear to change colour and move erratically due to hazy atmospheric conditions.

Approximately 12 per cent. of all sightings reported are from military and civilian radar facilities. It is fairly well established that some of these images are ground objects reflected from a layer of warm air above the earth (temperature inversion).

Temperature inversion reflections can give a return on a radar scope that is as sharp as that reflected from an aircraft. Speeds of these returns reportedly range from zero to fantastic rates. The 'objects' also appear to move in all directions. Such sightings have resulted in many fruitless intercept efforts.

Bearing out the theory of temperature inversion reflection is an incident which occurred in January, 1951, near Oakridge, Tennessee. Two Air Force aircraft attempted to intercept an unidentified 'object' and actually established a radar 'lock' on the object. Their altitude at the time was 7,000 ft. The unidentified object, according to their radar, appeared to be at an elevation of 10 to 15 degrees. Three passes were made in an attempt to close on the object.

In each instance the pilots reported that their radar led them first upward and then down toward a specific point on the ground. (One scientific theory holds that light can be similarly reflected from a layer of warm air above the Earth. If this proves to be correct, many visual night sightings could be accounted for.)

There are a small number of unexplained reports which involve a combination of seeing the object and detecting it on radar simultaneously. In each case the object appeared at night time and had the appearance of simple lights.

Ionized clouds have probably caused some unidentified radar returns. Thunderstorms are identifiable by radar, and radar is used aboard some aircraft and ships to avoid them. Radar returns have also been received from birds, ice formations in the air, balloons, ground reflections, frequency interference between other radar stations, and windborne objects. Obviously such returns are very difficult to identify, especially when they occur during darkness.

As stated earlier, the difficulty of evaluating reports of all types is based largely upon the lack of basic data surrounding the sighting. It is felt that the detailed questionnaire will remedy the situation in part.

In addition, special photographic equipment has been developed for distribution to selected air base control towers and Air Defence Command radar sites. This equipment consists of a diffraction grating camera which separates light into its component parts (spectrum) and registers them on film. The principle involved is that used by astronomers in determing the composition of the stars. In this manner Air Force scientists may be able to determine the source of unidentified lights. As yet, no photographs from these cameras have been received.

There have been some misconceptions concerning the Air Force handling of 'flying saucer' reports. One of these misconceptions is that the Air Force is either withholding 'flying saucer' information from the public or cloaking it beneath a security classification. This is untrue.

The names of the persons involved in the sightings are withheld in respect of their privacy. They are free, however, to say what they please. Reports which divulge the capabilities of our aircraft, radar, and electronic equipment are classified for obvious reasons. All other information with respect to sightings is a matter of public record.

Another misconception centres about photographs of 'flying saucers.' The Air Force does not possess photographs which prove the existence of 'flying saucers.' Because still photographs can be so easily faked, either by using a mock-up or model against a legitimate background, or by retouching the negative, they are practically worthless as evidence. Innumerable objects, from ashtrays to wash basins, have been photographed while sailing through the air. Many such photographs have been published without revealing the true identity of the objects.

More attention is given to moving pictures of unidentified flying objects since they are more difficult to fake. However, only a very few movie-type films have been received by the Air Force and they reveal only pinpoints of light moving across the sky. The Air Force has been unable to identify the source of these lights. The images are too small to analyze properly. Since ownership of these films remains with the persons taking them the Air

Force is not in a position to give them out. The owners may do with them as they please.

Although hoaxes comprise but a small percentage of total reports, some of them prove to be the most sensational and the most publicized. However, to ensure that the Air Force will not embarrass individuals or groups who are sincere in their beliefs or who may be victims of such hoaxers, the facts brought out in the investigations of these false reports are generally not made public. Unfortunately, this policy has often given the erroneous impression that the Air Force is deliberately denying or withholding information which, if revealed, would prove the existence of 'saucers.'

The Air Force has stated in the past, and reaffirms at the present time, that unexplained aerial phenomena are not a secret weapon, missile, or aircraft, developed by the United States. None of the three military departments nor any other agency in the Government is conducting experiments, classified or otherwise, with flying objects which could be a basis for the reported phenomena.

By the same token, no authentic physical evidence has been received establishing the existence of spaceships from other planets."

A NOTE ON A PAPER BY D. J. H. WORT

By J. A. Yates

Calculations made by myself do not agree at all well with those of Mr. Wort* and the main reason for this is, I think, that his equation—(1) p. 169 for the equilibrium constant K_a (K'_p as Mr. Wort designates) is misleading and leads to erroneous results for K_a. This can be seen readily almost at a glance, for according to the equation at temperatures below about 2,900° K the equilibrium constant would be negative!

It can be shown that K_a is related to the ΔH change by the expression

$$\frac{d \ln K_a}{dT} = \frac{\Delta H}{RT^2} \qquad \ldots \quad \ldots \quad \ldots \quad (a)$$

where ΔH is the change in heat content for a reaction.

For the reaction $2H \rightleftharpoons H_2$, $\Delta H = -104000$ calories per gram molecule of molecular hygrogen.

Using the integrated form of (*a*) and the fact that at 3000° K, H_2 is 9·03 per cent. dissociated into atomic hydrogen I was able to obtain K_a at any temperature and hence x in the expression

$$\begin{array}{ccc} H & + & H \rightarrow H_2 \\ (2-x) & & x/_2 \end{array}$$

The calculations, which involve the determination of heat capacities at different temperatures using statistical mechanics, are rather lengthy but the final results are expressed in the graph (Fig. 1).

With regard to the dilute monatomic hydrogen, Mr. Wort's results and mine are in substantial agreement although my values of exhaust velocity are

* D. J. H. Wort, "The Atomic Hydrogen Rocket," *J.B.I.S.*, **12** (4), 167, July, 1953.

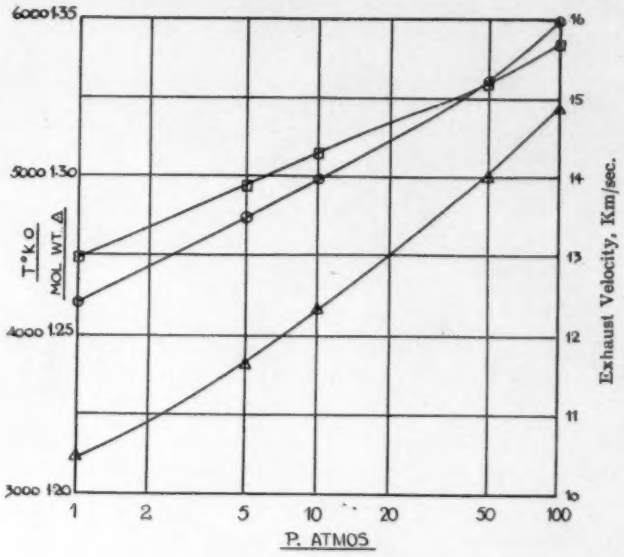


FIG. 1.

a little lower than those quoted in the article, which may well be due to differences in the means of calculation of γ.

When one considers the problem of the storage of atomic hydrogen, however, it seems that these calculations of high jet velocities are wasted, since (as I shall show) atomic hydrogen is not very permanent.

It is convenient first to consider gaseous atomic hydrogen which has been produced by passing molecular hydrogen through an electric arc between tungsten electrodes at several thousand degrees. In a current of gas the atomic hydrogen can be detected at some distance from the point of production. That this is so is due to the fact that, when two hydrogen atoms do collide to form a hydrogen molecule, sufficient energy is liberated to ensure the dissociation of the new molecule into atomic hydrogen again. The reaction to form molecular hydrogen can only occur when a third body (either a third atom or the wall of the containing vessel) is present to remove some of the energy liberated. Below I present an approximate treatment on the basis of the simple kinetic theory and one or two arbitrary assumptions about the reaction conditions, in order to obtain an estimate of the rate of loss of atomic hydrogen from an originally pure sample by three body collision, etc.

In the liquid the density is much greater and three body collisions will take place more frequently, so that it would appear that the existence of liquid atomic hydrogen is less likely than that of the gaseous form. The addition of inert gases to the gas will increase the number of three body collisions for a given partial pressure of atomic hydrogen, thus leading to a shorter life.

Consider 1 gm. of atomic hydrogen in a spherical container of volume V (spherical so that the ratio of wall area to volume is at a minimum).

Number of atoms per cc. $= n = \dfrac{N}{V}$

where N is Avogadro's Number $\sim 6 \times 10^{23}$. Average velocity of atoms relative to one another can be shown to be:—

$$v = \sqrt{\frac{8\,RT}{\mu\,\pi}}$$

where μ is the reduced mol. weight

$$\frac{1}{\mu} = \frac{1}{M_1} + \frac{1}{M_2}$$

M_1 and M_2 are the mol. weights of the colliding species. Collision between two atoms takes place if their centres approach to within 2 radii of each other

$2r = \sigma$ the collision diameter

In effect then one atom sweeps out a volume $\pi\,\sigma^2\,v$ c.c./sec.

$\therefore$ Number of collisions per second by one atom

$$= \pi\,\sigma^2\,n\,v$$

$\therefore$ Total number of collisions (2 body)/sec./cc. of gas

$$= \tfrac{1}{2}\,\pi\,\sigma^2\,n^2\,v$$

Assume that three body collisions are effective if the third particle is present while the two colliding atoms are within 2σ of each other.

For the three body collisions consider a hypothetical "new gas" of H—H particles and H atoms. On the average the number of H—H particles is n'

$$n' = \tfrac{1}{2}\,\pi\,n^2\,\sigma_H{}^2 v\;\delta\,t$$

($\delta\,t$ is the time that the centres of the atoms are within distance $2\,\sigma_H$ of each other).

$$\delta\,t = \frac{2\,\sigma_H}{v}$$

$$\therefore\; n' = \pi\,n^2\,\sigma_H{}^3$$

σ_H is the collision diameter of a hydrogen atom.

The "new gas" consists of n' H — H particles per cc. and $n - 2n'$ H atoms.

However, a rough calculation shows that n' is less than 1 per cent. of n for all reasonable conditions of temperature and pressure and so $n - 2n' = n$.

By the same method as above the number of collisions per second which are three body (i.e., H — H and H) can be shown to be:

$$\pi\,n\,n'\,\sigma'^2\,v' = 4\pi^2\,n^3\,\sigma_H{}^5\,v'$$

$$\sigma' = \frac{\sigma_H + \sigma_{H\text{-}H}}{2}$$

Assume $\sigma_{H\text{-}H} \doteqdot 3\sigma_H$.

Then $\sigma' = 2\sigma_H$

$\therefore$. The rate of formation of H_2 in the bulk is initially $4\pi^2 n^3 \sigma_H^5 v' V$ molecules/gm./sec.

$$= 4\pi^2 n^3 \sigma_H^5 \sqrt{\frac{8\,RT\,3}{\pi M_H 2}}\; V \qquad M_H = 1$$

Also since $n = \frac{N}{V}$

$$\frac{dH_2}{dt} = 8\pi \frac{N^2}{V^2} \sigma_H^5 \sqrt{3\pi RT} \quad \text{gm./sec./gm. H.}$$

On substituting actual values in this expression we obtain

$$\frac{dH_2}{dt} \doteqdot 10^{13} \frac{\sqrt{T}}{V_2} \quad \text{gm./sec./gm. H}$$

Thus if the gas is stored at 1 atmosphere and $T = 273°$ K, $V = 2{\cdot}24 \times 10^4$ cc.

$$\text{Then } \frac{d\,H_2}{dt} = \frac{10^{13}\sqrt{273}}{2{\cdot}24^2 \times 10^8} \doteqdot 3 \times 10^5 \text{ gm./sec./gm. H}$$

This of course is explosive!

Further formation of H_2 can take place at the walls of the container but calculations which I shall not include here indicate that recombination at the walls is much less than that in the gas at pressures above a few *mm* Hg and can be safely neglected. This assumes of course that the material of the walls has no catalytic effect which most metals do have in fact.

To sum up then it appears that the use of atomic hydrogen as a rocket fuel is impossible, since it cannot be stored in a compressed or condensed form long enough to enable it to be used in the rocket motor.

FUNDAMENTALS OF SPACE NAVIGATION

By Derek F. Lawden, M.A.

SUMMARY

The conditions to be satisfied by a rocket trajectory connecting two terminal points, if the fuel expenditure is to be a minimum, are given for the general case of an arbitrary gravitational field. Application is made to the problem of transfer between two coplanar orbits described under an inverse square law of force. Equations representing the solution to this problem, when the time of transit is specified, are calculated. The solution, when the time of transit is not a given quantity, is shown to be identical with that obtained previously. A method of calculating numerically the set of minimal trajectories issuing from a given terminal in a general field is outlined.

1. General Theory

The equations of motion of a rocket moving in the plane of rectangular cartesian axes Ox, Oy are

$$\ddot{x} + f = -\frac{lc}{M}\frac{dM}{dt} \qquad \ddot{y} + g = -\frac{mc}{M}\frac{dM}{dt}, \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

M being the rocket mass at time t, c the jet velocity, (l, m) the direction cosines of the direction of motor thrust and $(-f, -g)$ the resolutes in the directions fo

the axes of the resultant force per unit mass acting on the rocket due to the gravitational field by which it is surrounded. We shall regard f and g as explicit functions of x, y and t only.

Squaring and adding equations (1), since $l^2 + m^2 = 1$, we obtain after extraction of a square root

$$-\frac{c}{M}\frac{dM}{dt} = \left\{(\ddot{x}+f)^2 + (\ddot{y}+g)^2\right\}^{\frac{1}{2}}, \quad .. \quad .. \quad .. \quad .. \quad (2)$$

from which, by integration over the time interval (t_0, t_1), we calculate that

$$c \log \frac{M_0}{M_1} = \int_{t_0}^{t_1} \left\{(\ddot{x}+f)^2 + (\ddot{y}+g)^2\right\}^{\frac{1}{2}} dt \quad .. \quad .. \quad .. \quad (3)$$

M_0, M_1 being the rocket's mass at the beginning and end of the interval.

The transfer of a rocket between two terminal points in a gravitational field, the rocket track being selected so that the fuel expenditure is minimized, involves the minimization of the integral in equation (3) with respect to variation of the functions $x(t)$ and $y(t)$.

This problem has been solved in general form by the author, allowance having been made for an atmospheric resistance force in addition to the gravitational attraction and the solution will be found in reference 1. We shall here state the form the results take in the absence of all forces but the motor thrust and gravity.

A minimal trajectory comprises a number of arcs of null-thrust, i.e., arcs having equations

$$x = X(t) \qquad y = Y(t), \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad (4)$$

where X and Y are functions satisfying the differential equations

$$\ddot{x} + f = \ddot{y} + g = 0. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad (5)$$

At a junction between two such arcs, an impulsive thrust must be applied. The conditions to be satisfied across such a junction are specified in the following manner. Associated with the null-thrust arc having equations (4), are two auxiliary functions $u(t)$ and $v(t)$, which we shall refer to as the *primers* for a reason to be given later and which are governed by the differential equations

$$\ddot{u} + u\frac{\partial f}{\partial x} + v\frac{\partial g}{\partial x} = 0$$

$$\ddot{v} + u\frac{\partial f}{\partial Y} + v\frac{\partial g}{\partial Y} = 0. \qquad (6)$$

Here $\partial f/\partial X$ is that function of t obtainable from $f(x, y, t)$ by differentiating partially with respect to x and then substituting for x and y from equations (4). Equations (6) are linear in u and v and define these functions in terms of t and four arbitrary constants of integration.

Across a junction on a minimal trajectory, u and v and their first derivatives $\dot{u}$ and $\dot{v}$ must be continuous. It is also necessary that at the junction we should have

$$u^2 + v^2 = 1 \quad u\dot{u} + v\dot{v} = \tfrac{1}{2}\frac{d}{dt}(u^2 + v^2) = 0 \qquad .. \quad .. \quad .. \quad (7)$$

and that (u, v) should represent the direction cosines of the direction of the impulsive thrust applied to the rocket at the junction.

At all points on the trajectory it is a requirement that

$$u^2 + v^2 \leqslant 1, \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad (8)$$

and this condition, together with equations (7), shows that $(u^2 + v^2)$ must take a maximum value at a junction.

Impulses may be applied at either terminal point provided that equations (7) are satisfied there and provided that (u, v) are the direction cosines of the direction of the thrust.

Boundary conditions must also be satisfied at the terminals, viz. x and y must take prescribed values there and we shall further assume that the rocket velocity is specified at the terminals, in which case $\dot{x}$ and $\dot{y}$ are also prescribed at the terminals.

Finally the instants of departure and arrival may or may not be given quantities. If neither are specified, we may minimize with respect to both and then it is necessary that at both the terminals

$$uf + vg + \dot{u}\dot{X} + \dot{v}\dot{Y} = 0 \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad (9)$$

At a terminal where the instant of arrival or departure is given, this latter condition is no longer applicable.

Any combination of null-thrust arcs for which all these conditions are satisfied provides us with a rocket trajectory with respect to variations of which the integral of equation (3) is stationary. Amongst the set of such trajectories, we may seek the absolute minimal track by direct comparison of the fuel expenditures corresponding to each.

It will be found that if we further limit the stationary track to have a certain fixed number of junctions, the number of parameters whose value is open to choice is exactly equal to the number of conditioning equations. It follows that there will exist only a finite number of stationary tracks of each type. Thus if our stationary track is to comprise three null-thrust arcs separated by two junctions, each such arc is a solution of the equations (5) and hence depends on four arbitrary constants, i.e., twelve in all. The primers u and v provide similarly a further twelve arbitrary constants. If neither the instant of departure nor that of arrival is specified, twenty-six quantities have now to be reckoned as at our disposal. The instants of arrival of the rocket at the two junctions make then a total of twenty-eight parameters. In regard to the conditions to be satisfied, the continuity of the quantities u, v, $\dot{u}$, $\dot{v}$ across the two junctions yields eight, and conditions (7), to be satisfied at both junctions, provide a further four. Since the ratio $u : v$ is governed by the direction of the thrust at each junction, two more equations are available. The rocket co-ordinates (x, y) are clearly continuous across a junction and, due to this, four more conditions have to be satisfied. Finally, at the terminals, condition (9) is to be satisfied and the quantities $x, y, \dot{x}, \dot{y}$ are given; a further ten conditions.

In all, twenty-eight conditions are to be satisfied, in agreement with the number of arbitrary parameters.

The extension of the above theory to the calculation of stationary tracks in three dimensions proceeds in the obvious fashion.

In practice, it will only rarely be the case that f and g are entirely independent of t, this in view of the motions of astronomical bodies. However, over large portions of a rocket track, it will normally be the case that f and g do not depend explicitly upon t. For example, for a transit between the Earth and Mars, the gravitational field of the sun will be predominant over the major portion of the trajectory and thus, taking axes fixed relative to this body, f and g will be functions of x and y (and possibly z) alone during this part of the passage. In such a case, the equations (6) are found to possess[1] a first integral, viz.

$$K = \dot{u}\dot{X} + \dot{v}\dot{Y} + uf + vg = \text{constant}, \quad .. \quad .. \quad .. \quad .. \quad (10)$$

which may be employed as a substitute for either of the equations (6). If K_-, K_+ represent the values taken by K on either side of a junction, since u, v, f, g are continuous across the junction

$$K_+ - K_- = \dot{u}(\dot{X}_+ - \dot{X}_-) + \dot{v}(\dot{Y}_+ - \dot{Y}_-). \quad .. \quad .. \quad .. \quad (11)$$

But the velocity increments $(\dot{X}_+ - \dot{X}_-)$ and $(\dot{Y}_+ - \dot{Y}_-)$ are proportional to the direction cosines of the impulsive thrust at the junction, viz. (u, v). Hence

$$K_+ - K_- = k(u\dot{u} + v\dot{v}) = 0 \quad .. \quad .. \quad .. \quad .. \quad .. \quad (12)$$

by equation (7). We have therefore shown that K is continuous over a junction. It follows that if the minimal trajectory is entirely composed of arcs described under field conditions not varying with t, K will take the same constant value over the whole trajectory. In particular, if the times of departure and arrival are not fixed, so that condition (9) is to be satisfied, $K = 0$ everywhere.

2. Inverse Square Law of Force

In this section we will calculate the form of the primers u and v over a conic trajectory described under an inverse square law of force. The practical importance of such a trajectory was explained in the last section.

Taking axes Ox, Oy in the plane of the trajectory, O being the centre of attraction, if (r, θ) are polar co-ordinates relative to O as pole and Ox as initial line, the equation of the trajectory may be taken in the form

$$1/r = p\left\{1 + e\cos(\theta + \gamma)\right\}, \quad .. \quad .. \quad .. \quad .. \quad .. \quad (13)$$

where $1/p$ is the semi-latus rectum, e is the eccentricity and γ is an angle determining the orientation of the trajectory in the xy-plane. We have also the angular momentum equation

$$r^2\dot{\theta} = \sqrt{\mu/p}, \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad (14)$$

where μ/r^2 is the attraction per unit mass of the rocket.

Differentiating equation (13) with respect to t, we find that

$$\dot{r}/r^2 = pe\sin(\theta+\gamma).\dot{\theta}$$

and, in view of equation (14), this can be written

$$\dot{r} = \sqrt{\mu p}e\sin(\theta+\gamma). \quad \ldots\ldots\ldots\ldots\ldots\ldots (15)$$

The quantities f and g are given by the equations

$$f = \frac{\mu}{r^2}\cos\theta = \frac{\mu x}{r^3} = \frac{\mu x}{(x^2+y^2)^{3/2}}$$

$$g = \frac{\mu}{r^2}\sin\theta = \frac{\mu y}{r^3} = \frac{\mu y}{(x^2+y^2)^{3/2}}. \quad (16)$$

Whence

$$\frac{\partial f}{\partial x} = \mu\frac{y^2-2x^2}{(x^2+y^2)^{5/2}} = \mu\cdot\frac{1-3\cos^2\theta}{r^3} \quad \ldots\ldots (17)$$

$$\frac{\partial f}{\partial y} = \frac{\partial g}{\partial x} = -\frac{3\mu xy}{(x^2+y^2)^{5/2}} = -\frac{3\mu\sin\theta\cos\theta}{r^3} \quad \ldots\ldots (18)$$

$$\frac{\partial g}{\partial y} = \mu\cdot\frac{x^2-2y^2}{(x^2+y^2)^{5/2}} = \mu\cdot\frac{1-3\sin^2\theta}{r^3} \quad \ldots\ldots (19)$$

and these quantities may now be substituted in equations (6), it being understood that r is given in terms of θ by equation (13).

Clearly θ is more suitable as the independent variable of equations (6) than is t in this context. Using primes to denote differentiations with respect to θ, we have

$$\ddot{v} = v''\dot{\theta}^2 + v'\ddot{\theta}. \quad \ldots\ldots\ldots\ldots\ldots\ldots (20)$$

Equation (14) gives

$$\dot{\theta} = \frac{1}{r^2}\sqrt{\frac{\mu}{p}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (21)$$

and this, upon differentiation with respect to t, leads to

$$\ddot{\theta} = -\frac{2}{r^3}\dot{r}\sqrt{\frac{\mu}{p}} = -\frac{2\mu e}{r^3}\sin(\theta+\gamma), \quad \ldots\ldots\ldots\ldots (22)$$

having employed equation (15).

Equation (20) can now be written

$$\ddot{v} = \frac{\mu}{pr^4}v'' - \frac{2\mu e}{r^3}v'\sin(\theta+\gamma) \quad \ldots\ldots\ldots\ldots (23)$$

and hence the second of equations (6) is equivalent to

$$\left\{1+e\cos(\theta+\gamma)\right\}v'' - 2ev'\sin(\theta+\gamma) - 3u\sin\theta\cos\theta + v(1-3\sin^2\theta) = 0. \quad (24)$$

Simplification of this equation may be effected by changing to new dependent variables (w, z), related to the variables (u, v) according to the equations

$$w = (u \cos\theta + v \sin\theta)\left\{1 + e\cos(\theta + \gamma)\right\} \quad \ldots \quad \ldots \quad \ldots \quad (25)$$

$$z = (-u \sin\theta + v \cos\theta)\left\{1 + e\cos(\theta + \gamma)\right\}. \quad \ldots \quad \ldots \quad \ldots \quad (26)$$

In terms of w and z, equation (24) will be found to take the form

$$z'' + 2w' = 0. \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (27)$$

Equation (27) integrates immediately to yield

$$z' = Ae - 2w \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (28)$$

A being an arbitrary constant.

Since f and g do not depend explicitly upon t, equation (10) is available. Now $x = r\cos\theta$ and hence differentiating with respect to t

$$\begin{aligned}\dot{x} &= \dot{r}\cos\dot{\theta} - r\dot{\theta}\sin\theta \\ &= \sqrt{\mu p}\, e \sin(\theta + \gamma)\cos\theta - \sqrt{\mu p}\left\{1 + e\cos(\theta + \gamma)\right\}\sin\theta \\ &= \sqrt{\mu p}\,(e\sin\gamma - \sin\theta), \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (29)\end{aligned}$$

equations (13) and (15) having been employed in the reduction.

Differentiating equation (29) again, we obtain

$$\ddot{x} = -\sqrt{\mu p}\cos\theta\dot{\theta} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (30)$$

Similarly we may show that since $y = r\sin\theta$,

$$\dot{y} = \sqrt{\mu p}\,(e\cos\gamma + \cos\theta) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (31)$$

$$\ddot{y} = -\sqrt{\mu p}\sin\theta\dot{\theta}. \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (32)$$

Now $f = -\ddot{x}$, $g = -\ddot{y}$, so that equation (10) takes the form

$$\left\{(e\sin\gamma - \sin\theta)u' + (e\cos\gamma + \cos\theta)v' + u\cos\theta + v\sin\theta\right\}\dot{\theta} = \frac{K}{\sqrt{\mu p}}$$

which, by reference to equations (21) and (13), is seen to be equivalent to

$$\left\{(e\sin\gamma - \sin\theta)u' + (e\cos\gamma + \cos\theta)v' + u\cos\theta + v\sin\theta\right\}\left\{1 + e\cos(\theta + \gamma)\right\}^2 = \frac{K}{\mu p^2}. \quad (33)$$

Transforming to the variables w and z as defined by equations (25) and (26), this latter equation becomes

$$e(1 + e\cos\psi)\sin\psi\, w' + (1 + e\cos\psi)^2 z' + (e^2 + 2 + 3e\cos\psi)w = \frac{K}{\mu p^2} \quad (34)$$

where ψ has been written for $\theta + \gamma$.

Equations (28) and (34) specify between them the functions w and z. Elimination of z' between them provides us with the equation

$$(1 + e\cos\psi)\sin\psi\, w' + (e - \cos\psi - 2e\cos^2\psi)w = \frac{K}{\mu p^2 e} - A(1 + e\cos\psi)^2. \quad (35)$$

The integrating factor for this first order linear equation is found to be $(1 + e\cos\psi)^{-2}\sin^{-2}\psi$ and the solution for w accordingly

$$w = (1 + e\cos\psi)\left(A\cos\psi + Be\sin\psi + \frac{K}{\mu p^2 e} I\sin\psi\right) \quad .. \quad .. \quad (36)$$

where

$$I = \int_\alpha^\psi \frac{d\omega}{(1 + e\cos\omega)^2\sin^2\omega} \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad (37)$$

and α is arbitrary.

This integral may be evaluated by a change of variable to $\tan\frac{1}{2}\psi$. Choosing α appropriately, it will be found to take one of the forms

$$\frac{1}{2(1-e)^2}\tan\frac{\psi}{2} - \frac{1}{2(1+e)^2}\cot\frac{\psi}{2} - \frac{6e^2}{(1-e^2)^{5/2}}\tan^{-1}\left(\sqrt{\frac{1-e}{1+e}}\tan\frac{\psi}{2}\right) + \frac{e^2}{(1-e^2)^2}\cdot\frac{\sin\psi}{1+e\cos\psi} \quad (A)$$

$$\frac{1}{2(e-1)^2}\tan\frac{\psi}{2} - \frac{1}{2(e+1)^2}\cot\frac{\psi}{2} \quad .. \quad .. \quad .. \quad .. \quad (38)$$

$$- \frac{6e^2}{(e^2-1)^{5/2}}\tanh^{-1}\left(\sqrt{\frac{e-1}{e+1}}\tan\frac{\psi}{2}\right) + \frac{e^2}{(e^2-1)^2}\cdot\frac{\sin\psi}{1+e\cos\psi} \quad (B)$$

$$\frac{1}{40}\tan^5\frac{\psi}{2} + \frac{1}{8}\tan^3\frac{\psi}{2} + \frac{3}{8}\tan\frac{\psi}{2} - \frac{1}{8}\cot\frac{\psi}{2} \quad (C)$$

form (A) being appropriate when $e < 1$, form (B) when $e > 1$ and form (C) when $e = 1$. When $\psi = \alpha$, the integral must be zero and hence each of the above expressions vanishes when $\psi = \alpha$. This determines the appropriate value of α in each case.

Substituting from equation (36) into equation (28), we obtain upon integration for z

$$z = -A\sin\psi\,(2 + e\cos\psi) + B(1 + e\cos\psi)^2 - \frac{2K}{\mu p^2 e}\int_\alpha^\psi d\nu \int_\alpha^\nu \frac{(1 + e\cos\nu)\sin\nu}{(1 + e\cos\omega)^2\sin^2\omega}\, d\omega + C^1 \quad .. \quad (39)$$

where C' is a further arbitrary constant. Reversing the order of integration in the repeated integral, it may be evaluated in the form

$$\frac{1}{2e}\Big[\cot\alpha - \cot\psi - (1 + e\cos\psi)^2 I\Big]. \quad .. \quad .. \quad .. \quad .. \quad (40)$$

Equation (39) is therefore equivalent to

$$z = -A \sin\psi\,(2 + \cos\psi) + B\,(1 + e\cos\psi)^2 + \frac{K}{\mu p^2 e^2}\left[\cot\psi + (1 + e\cos\psi)^2 I\right] + C, \quad (41)$$

a constant term having been added to C' to give C.

Introducing new dependent variables (U, V) defined by the equations

$$U = \frac{w}{1 + e\cos\psi} = u\cos\theta + v\sin\theta$$
$$V = \frac{z}{1 + e\cos\psi} = -u\sin\theta + v\cos\theta, \quad (42)$$

we may write equations (36) and (41) thus

$$U = A\cos\psi + Be\sin\psi + \frac{K}{\mu p^2 e} I\sin\psi \quad (43)$$

$$V = -A\sin\psi + B(1 + e\cos\psi) + \frac{C - A\sin\psi}{1 + e\cos\psi} + \frac{K}{\mu p^2 e^2}\left[\frac{\cot\psi}{1 + e\cos\psi} + (1 + e\cos\psi)I\right]. \quad (44)$$

Taking rectangular cartesian axes $O'u$, $O'v$ in a plane, we may interpret the quantities (u, v) as the resolutes of a certain displacement vector $O'P$. Equations (42) then show that (U, V) are to be interpreted as the resolutes of the same vector with respect to axes $O'U$, $O'V$ making an angle θ with the axes $O'u$, $O'v$ as indicated in the figure. At a junction, (u, v) represent the direction cosines of the thrust direction and hence, if we suppose $O'u$, $O'v$ to be in the directions of the axes Ox, Oy respectively, the vector $O'P$ will then be a unit vector in the direction of the thrust. Also, $O'U$, $O'V$ will be in the directions of the radius vector r and the perpendicular to this line respectively. (U, V) are accordingly the resolutes of the unit vector in the direction of the thrust, taken along the radial and transverse directions. If, therefore, ϕ is the angle made by the direction of the thrust with the forward transverse direction, the following equations are valid at a junction

$$U = \sin\phi \qquad V = \cos\phi. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad (45)$$

Differentiating equations (42) with respect to t, we obtain

$$\dot{U} = V\dot{\theta} + \dot{u}\cos\theta + \dot{v}\sin\theta$$
$$\dot{V} = -U\dot{\theta} - u\sin\theta + \dot{v}\cos\theta \quad (46)$$

or, employing equation (21),

$$\sqrt{\frac{\mu}{p}}\,(U' - V) = (\dot{u}\cos\theta + \dot{v}\sin\theta)r^2$$
$$\sqrt{\frac{\mu}{p}}\,(V' + U) = (-\dot{u}\sin\theta + \dot{v}\cos\theta)r^2 \quad (47)$$

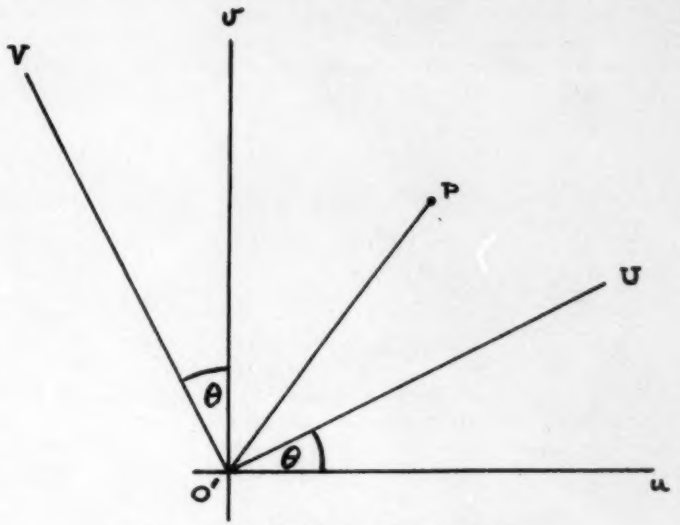


FIG. 1. Relationship between uv- and UV-planes.

But $\dot{u}$, $\dot{v}$, r and θ are to be continuous across a junction and it therefore follows that the quantities

$$\frac{1}{p^{\frac{1}{2}}}(U' - V), \qquad \frac{1}{p^{\frac{1}{2}}}(V' + U) \qquad .. \quad .. \quad .. \quad .. \quad .. \quad (48)$$

are also continuous across a junction.

We can now formulate equations expressing the conditions described in Section 1. If the transit time is a given quantity, there will also be an equation expressing this fact. The formulae, from which this equation may be derived, will be found in any standard Dynamics textbook. The aggregate of equations so obtained will be found sufficient to determine the parameters A, B, C, K, p, e, γ associated with each conic arc. We shall not examine this system of equations in detail in this paper, however, but will confine our attention to the case of a two impulse transfer between two given coplanar orbits, the time of transit being unspecified and to be chosen so as to minimize the fuel expenditure. This problem has already been solved by another method in reference 2 and by showing that our present procedure leads to the same result as previously, we shall provide a check, not only upon our previous work, but also upon the general procedure outlined in Section 1 of this paper.

3. Two Impulse Transfer Between Coplanar Orbits

Let (p_1, e_1, γ_1), (p_2, e_2, γ_2) be the terminal orbits and let (p, e, γ) be the orbit of transfer. Let (r_1, θ_1), (r_2, θ_2) be the polar co-ordinates of the two junctions. Let (A_1, B_1, C_1), (A_2, B_2, C_2) be the values of the parameters upon which (U, V)

are dependent, corresponding to the two terminal orbits and let (A, B, C) denote their values over the transfer orbit. Let ϕ_1, ϕ_2 be the angles made by the direction of impulsive thrust with the forward transverse direction at each junction. Putting

$$s_1 = 1/r_1,\ s_2 = 1/r_2,\ \psi_1 = \theta_1 + \gamma_1,\ \psi = \theta_1 + \gamma,$$
$$\psi' = \theta_2 + \gamma,\ \psi_2 = \theta_2 + \gamma_2 \quad (49).$$

we abstract from reference 2 the following equations valid for the two impulses

$$p\alpha \sin \psi = (s_1 - p^{\frac{1}{2}}D_1) \tan \phi_1 \quad .. \quad .. \quad .. \quad .. \quad .. \quad (50)$$

$$p_1\alpha_1 \sin \psi_1 = (s_1 - p^{\frac{1}{2}}{}_1D_1) \tan \phi_1 \quad .. \quad .. \quad .. \quad .. \quad .. \quad (51)$$

$$p\alpha \sin \psi' = (s_2 - p^{\frac{1}{2}}D_2) \tan \phi_2 \quad .. \quad .. \quad .. \quad .. \quad .. \quad (52)$$

$$p_2\alpha_2 \sin \psi_2 = (s_2 - p^{\frac{1}{2}}{}_2D_2) \tan \phi_2 \quad .. \quad .. \quad .. \quad .. \quad .. \quad (53)$$

where D_1, D_2 are constants of the impulses having the significance explained in reference 2 (where they are denoted by A_1 and A_2).

Also, since r is continuous across each junction, there are the equations

$$s_1 = p_1(1 + e_1 \cos \psi_1) = p(1 + e \cos \psi) \quad .. \quad .. \quad .. \quad .. \quad (54)$$

$$s_2 = p_2(1 + e_2 \cos \psi_2) = p(1 + e \cos \psi') \quad .. \quad .. \quad .. \quad .. \quad (55)$$

Minimization is to be effected with respect to the time of transit and hence $K = 0$ everywhere. Equations (43)–(45) accordingly yield

$$A_1 \cos \psi_1 + B_1e_1 \sin \psi_1 = A \cos \psi + Be \sin \psi = \sin \phi_1 \quad .. \quad .. \quad (56)$$

$$-A_1 \sin \psi_1 + B_1(1 + e_1 \cos \psi_1) + \frac{C_1 - A_1 \sin \psi_1}{1 + e_1 \cos \psi_1}$$
$$= -A \sin \psi + B(1 + e \cos \psi) + \frac{C - A \sin \psi}{1 + e \cos \psi} = \cos \phi_1 \quad .. \quad (57)$$

$$A_2 \cos \psi_2 + B_2e_2 \sin \psi_2 = A \cos \psi' + Be \sin \psi' = \sin \phi_2 \quad .. \quad (58)$$

$$-A_2 \sin \psi_2 + B_2(1 + e_2 \cos \psi_2) + \frac{C_2 - A_2 \sin \psi_2}{1 + e_2 \cos \psi_2}$$
$$= -A \sin \psi' + B(1 + e \cos \psi') + \frac{C - A \sin \psi'}{1 + e \cos \psi'} = \cos \phi_2 \quad .. \quad (59)$$

The continuity across each junction of the quantities (48), provides us with further equations, viz.

$$\frac{1}{p_1^{\frac{1}{2}}}\left(\frac{A_1 \sin \psi_1 - C_1}{1 + e_1 \cos \psi_1} - B_1\right) = \frac{1}{p^{\frac{1}{2}}}\left(\frac{A \sin \psi - C}{1 + e \cos \psi} - B\right) \quad .. \quad .. \quad (60)$$

$$\frac{1}{p_1^{\frac{1}{2}}}\left[\frac{C_1e_1 \sin \psi_1 - A_1e_1 - A_1 \cos \psi_1}{(1 + e_1 \cos \psi_1)^2}\right] = \frac{1}{p^{\frac{1}{2}}}\left[\frac{Ce \sin \psi - Ae - \mathrm{A} \cos \psi}{(1 + e \cos \psi)^2}\right] \quad (61)$$

$$\frac{1}{p_2^{\frac{1}{2}}}\left(\frac{A_2 \sin\psi_2 - C_2}{1+e_2\cos\psi_2} - B_2\right) = \frac{1}{p^{\frac{1}{2}}}\left(\frac{A\sin\psi' - C}{1+e\cos\psi'} - B\right) \quad .. \quad .. \quad (62)$$

$$\frac{1}{p_2^{\frac{1}{2}}}\left[\frac{C_2 e_2 \sin\psi_2 - A_2 e_2 - A_2\cos\psi_2}{(1+e_2\cos\psi_2)^2}\right] = \frac{1}{p^{\frac{1}{2}}}\left[\frac{Ce\sin\psi' - Ae - A\cos\psi'}{(1+e\cos\psi')^2}\right]. \quad (63)$$

All the conditions given in Section 1 have now been employed, the second of conditions (7) being implicit in our assumption of the continuity of K.

The equations (59 to 60) are suffieient to determine the twenty unknowns p, e, γ, s_1, s_2, θ_1, θ_2, ϕ_1, ϕ_2, D_1, D_2, A_1, B_1, C_1, A_2, B_2, C_2, A, B, C. This system of equations is equivalent to that of eleven equations between eleven unknowns given in reference 2. The manner by which this may be proved we will now indicate.

Eliminating A_1, B_1, C_1, B, C from equations (56), (57), (60) and (61) and solving for A, we may calculate that

$$A = \frac{\sin\phi_1(1+e\cos\psi)\left\{\sqrt{\frac{p}{p_1}}\sin\psi + e_1\sin\psi_1\cos\psi - \sin\psi(1+e_1\cos\psi_1)\right\}}{e_1\sin\psi_1(1+e\cos\psi) - e\sin\psi(1+e_1\cos\psi_1) - \cos\phi_1\sin\psi} \quad (64)$$

Employing equations (50), (51) and (54), this latter equation may be reduced to

$$p^{\frac{1}{2}}eA = -\left(\frac{s_1}{D_1} - D_1\right)\sin\phi_1. \quad .. \quad .. \quad .. \quad .. \quad .. \quad (65)$$

From equation (56) we now obtain

$$Be\sin\psi = \sin\phi_1 - A\cos\psi \quad .. \quad .. \quad .. \quad .. \quad .. \quad (66)$$

and whence, from equations (50), (54) and (65), we deduce that

$$pe^2B = \frac{p^{\frac{1}{2}}e^2D_1 + p^{\frac{1}{2}}(s_1-p)(s_1-D^2)}{D_1(s_1 - p^{\frac{1}{2}}D_1)}\cos\phi_1. \quad .. \quad .. \quad .. \quad (67)$$

But equations (50) and (54) together imply that

$$p^2e^2 = (s_1-p)^2 + (s_1 - p^{\frac{1}{2}}D_1)^2\tan^2\phi_1 \quad .. \quad .. \quad .. \quad .. \quad (68)$$

Substituting for p^2e^2 from this latter equation in the right hand side of equation (67), we can now show that

$$pe^2B = \left(1 + \frac{p^{\frac{1}{2}}}{D_1}\right)(s_1-p)\cos\phi_1 + (s_1 - p^{\frac{1}{2}}D_1)\tan\phi_1\sin\phi_1. \quad .. \quad (69)$$

The second of equations (57) may be written in the form

$$B + C = (1+e\cos\psi)\cos\phi_1 + (2+e\cos\psi)(A\sin\psi - Be\cos\psi) \quad (70)$$

Substituting in the right hand side of this equation for A and B from equations

(65) and (69) and employing equations (50) and (54) to eliminate $\cos\psi$ and $\sin\psi$ respectively, we may express this relationship thus

$$B + C = \frac{s_1}{p}\cos\phi_1 - \frac{s_1 + p}{p^3 e^2}\left(1 + \frac{p^{\frac{1}{2}}}{D_1}\right)\Big[(s_1 - p)^2 + (s_1 - p^{\frac{1}{2}}D_1)^2 \times \tan^2\phi_1\Big]\cos\phi_1 \quad (71)$$

Equation (68) permits a reduction of this equation to the form

$$B + C = -\left(\frac{s_1 + p}{D_1 p^{\frac{1}{2}}} + 1\right)\cos\phi_1. \quad (72)$$

By means of an exactly parallel procedure, we may also show that

$$p^{\frac{1}{2}}eA = -\left(\frac{s_2}{D_2} - D_2\right)\sin\phi_2 \quad (73)$$

$$pe^2B = \left(1 + \frac{p^{\frac{1}{2}}}{D_2}\right)(s_2 - p)\cos\phi_2 + (s_2 - p^{\frac{1}{2}}D_2)\tan\phi_2\sin\phi_2 \quad (74)$$

$$B + C = -\left(\frac{s_2 + p}{D_2 p^{\frac{1}{2}}} + 1\right)\cos\phi_2. \quad (75)$$

Comparing equations (65), (69), (72) with equations (73)–(75), we observe that

$$\left(\frac{s_1}{D_1} - D_1\right)\sin\phi_1 = \left(\frac{s_2}{D_2} - D_2\right)\sin\phi_2 \quad (76)$$

$$\left(1 + \frac{p^{\frac{1}{2}}}{D_1}\right)(s_1 - p)\cos\phi_1 + (s_1 - p^{\frac{1}{2}}D_1)\tan\phi_1, \sin\phi_1 = \left(1 + \frac{p^{\frac{1}{2}}}{D_2}\right)(s_2 - p)\cos\phi_2 + (s_2 - p^{\frac{1}{2}}D_2)\tan\phi_2\sin\phi_2 \quad (77)$$

$$\left(\frac{s_1 + p}{D_1 p^{\frac{1}{2}}} + 1\right)\cos\phi_1 = \left(\frac{s_2 + p}{D_2 p^{\frac{1}{2}}} + 1\right)\cos\phi_2. \quad (78)$$

Equations (50)–(53), (54), (55), (76)–(78) form a set of eleven relationships between the eleven unknowns s_1, θ_1, ϕ_1, D_1, s_2, θ_2, ϕ_2, D_2, p, e, γ and represent the solution to this problem previously obtained in reference 2. This, then, affords a verification of the accuracy of the two methods of attack which have been proposed.

4. Numerical Computation of Minimal Trajectories

The fundamental differential equations in this field are equations (5) and (6). No difficulty will be experienced if it is desired to integrate these numerically in any practical case. All that is necessary is that formulae shall be available for the numerical calculation of the resolutes $(-f, -g)$ of the gravitational attraction at any point of space at a specified instant. In the case of a rocket track between two points of the solar system, standard astronomical

tables may be consulted for such information. The chief difficulty arises when attempting to fit tracks to given terminal conditions and time of transit. Some simplification results, if the time of transit is not specified, so that we require to minimize the fuel expenditure with respect to this quantity also and, since this will generally be the case, we will suppose it so in this Section. At the terminal of departure, the rocket will probably be in a circular satellite orbit about the Earth or some other body. Given such an orbit, the most satisfactory course would appear to be that of calculating a large number of representative minimal tracks fanning out from it at a large number of different instants of departure during the year and leading to different parts of the solar system. Such tracks could be computed by the thousand using an electronic computer, as soon as the latter had been programmed to deal with the problem and the information could then be used to compile handbooks for use by space navigators.

The preparation of such handbooks would of course involve computing with the general three-dimensional equations, but to illustrate the feasibility of this computation, we will restrict the argument to two dimensions.

With the rocket at some given point in space and with a given velocity, sufficient information is available to commence the integration of equations (5). Parallel with this process, we may carry out the numerical integration of equations (6) for the primers. To commence this latter computation, we must assume initial values of the primers and their first derivatives and since condition (9) is to be satisfied at the terminals, these values must be appropriately selected. It is clear that any three of these initial values are arbitrary. We continue the integration process until $u\dot{u} + v\dot{v} = 0$. This is one of the conditions (7) to be satisfied at a junction and hence we have now arrived at a suitable instant for the application of an impulsive thrust. The functions u and v therefore act as *primers*, initiating the short periods of thrust at any instant when they and their derivatives take certain critical values. Suppose that at this instant it is found that $u^2 + v^2 = k^2$. Modifying the primers by a scale factor $1/k$, we can thus ensure that the first of conditions (7) is also satisfied at the junction. The modified primers will continue to satisfy equations (6), condition (9) (at the terminal of departure) and the second of conditions (7). The scale factor $1/k$ not being arbitrary, only two of the ratios of the quantities u, v, $\dot{u}$, $\dot{v}$ are arbitrary initially and hence we can compute a double infinity of tracks emanating from the terminal.

At the junction (u, v) are the direction cosines of the thrust. Suppose an impulse J is applied in this direction. The values of x, y, $\dot{x}$, $\dot{y}$ immediately after the impulse are simply calculable and then we can continue our integration of equations (5). The quantities u, v, $\dot{u}$, $\dot{v}$ are continuous across the junction and hence the integration of equations (6) can also be continued. It is now necessary to take various trial values of J and to ascertain the manner in which the value of $u^2 + v^2$ when $u\dot{u} + v\dot{v}$ is next zero depends upon J. J must be varied numerically until conditions (7) are satisfied together. When the primers satisfy these conditions, another impulse is applicable and the above process is repeated to give the next arc.

It will normally be the case that the track is to terminate in a closed orbit

about some attracting body. The field being time invariant over this latter portion of the track, the quantity K (equation (10)) will be constant. We have yet to satisfy the condition (9), viz. $K = 0$ at the arrival terminal. Numerically, this will have to be done by varying one of the two initial arbitrary ratios $u : v : \dot{u} : \dot{v}$ until this condition has been satisfied. Only one of these ratios is effectively arbitrary therefore, and the final result will be a single infinity of tracks connecting the two terminal orbits.

In three dimensions, a set of ∞^3 minimal tracks, issuing from a single terminal, can be computed in the above manner. Although the number of parameters is admittedly large, the preparation of comprehensive handbooks for departure orbits from a given satellite station about the Earth, represents a few years' work only for a single modern electronic computer. The calculation will be assisted by the fact that over large portions of the track, the field of a single body will predominate and the numerical integration of equations (5) and (6) can be discontinued, use being made of the results of Section 3.

5. Departure from a Circular Orbit

The results of Section 3 are not applicable directly to the case of a rocket moving in a circular orbit about an attracting body, since this is the case $e = 0$ and equation (34) becomes

$$z' + 2w = K/p^2\mu \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad (79)$$

where p is now the reciprocal of the track's radius and this equation does not differ essentially from equation (27), i.e. the first integral of equations (6) is not distinct from the second of these equations. We shall accordingly associate the first of equations (6) with the first integral (79). In terms of the variables w and z, the first of equations (6) takes the form

$$w'' - 2z' - \frac{3w}{1 + e\cos\psi} = 0 \quad .. \quad .. \quad .. \quad .. \quad .. \quad (80)$$

or, in the case $e = 0$, it is

$$w'' - 2z' - 3w = 0 \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad (81)$$

Substituting for z' from equation (79), yields

$$w'' + w = 2K/p^2\mu, \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad (82)$$

to which the general solution is

$$w = A\sin(\theta + \beta) + 2K/p^2\mu. \quad .. \quad .. \quad .. \quad .. \quad .. \quad (83)$$

Whence

$$z = 2A\cos(\theta + \beta) - 3K\theta/p^2\mu + C \quad .. \quad .. \quad .. \quad .. \quad (84)$$

A, K, C, β being the four arbitrary constants of integration.

Equations (42) show that if $e = 0$

$$U = w, \qquad V = z. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad (85)$$

It is clear from the figure that

$$u^2 + v^2 = U^2 + V^2 \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad (86)$$

identically. Differentiating this equation, we obtain also

$$u\dot{u} + v\dot{v} = U\dot{U} + V\dot{V}. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad (87)$$

Since conditions (7) are to be satisfied at a junction, at such a point we must have

$$U^2 + V^2 = 1, \qquad U\dot{U} + V\dot{V} = (UU' + VV')\dot{\theta} = 0 \quad .. \quad .. \quad (88)$$

i.e., $UU' + VV' = 0$.

At a junction with the circular orbit therefore,

$$\left\{A \sin(\theta + \beta) + \frac{2K}{p^2\mu}\right\} A \cos(\theta + \beta)$$

$$- \left\{2A \cos(\theta + \beta) - \frac{3K\theta}{p^2\mu} + C\right\}\left\{2A \sin(\theta + \beta) + \frac{3K}{p^2\mu}\right\} = 0. \quad (89)$$

Assuming minimization with respect to the time of transit, $K = 0$ and hence

$$\sin(\theta + \beta)\left\{3A \cos(\theta + \beta) - 2C\right\} = 0. \ldots \quad .. \quad .. \quad .. \quad (90)$$

$(\theta + \beta)$ therefore takes one of the values 0, π, $\cos^{-1}\dfrac{2C}{3A}$ at the junction. The latter value for $(\theta + \beta)$ is found to lead to a minimum for $U^2 + V^2$ and is therefore invalid (*vide* Section 1). When $(\theta + \beta) = 0$,

$$U = 0, \; V = 2A + C \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad (91)$$

and to satisfy the first of conditions (88), we must choose A and C so that

$$V = 2A + C = \pm 1 \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad (92)$$

The direction cosines of the impulsive thrust referred to the radial and transverse directions are accordingly $(0, \pm 1)$. This implies that the thrust must be tangential, either with or against the motion.

The solution $(\theta + \beta) = \pi$ will be found to lead to conditions essentially identical with those just calculated.

The point on the orbit at which the impulse is to be applied is indeterminate, as is one of the constants A and C. A double infinity of tracks therefore issues from the circular orbit, all tangential to it. However, as explained in Section 4, one of the parameters A or C will have to be given a series of values, that value being finally selected which permits condition (9) to be satisfied at the far terminal. A single infinity of minimal tracks is therefore all that is available.

REFERENCES

(1) D. F. Lawden, "Stationary Rocket Trajectories" (to be published).
(2) D. F. Lawden, "Inter-Orbital Transfer of a Rocket," *Annual Report B.I.S.*, 321–333, December, 1952.

BRITISH INTERPLANETARY SOCIETY NEWS

Eighth Annual General Meeting

The Eighth Annual General Meeting was opened at Caxton Hall on December 5, 1953, when the Chairman, Mr. A. C. Clarke, drew attention to the main points in his printed report, which had previously been circulated to all members with the November, 1953 *Journal*.

On the proposal of Mr. E. Hope-Jones, seconded by Mr. P. W. Stone, the audited Balance Sheet and Accounts for the year ended September 30, 1953, was unanimously approved by the meeting.

The Chairman referred to a minor alteration in one of the Society's Articles, and it was therefore moved by Mr. G. E. V. Awdry that Article 30 be amended as indicated on the Agenda.

After being seconded by Mr. G. V. E. Thompson, the Resolution was put to the meeting and carried unanimously.

The Scrutineers report was then read, concerning the election of four new members of the Council by postal ballot.

The report gave the number of Ballot papers received as 657, and the names of those elected as follows:—

D. Hurden.
D. F. Lawden.
Dr. A. E. Slater.
R. A. Smith.

The Chairman expressed his pleasure in welcoming Messrs. D. F. Lawden and D. Hurden to the Council, and announced that it would be also necessary for the Council to consider the question of co-opting a further member, in view of the resignation of Mr. H. E. Ross on the grounds of ill-health.

A general discussion then took place on various aspects of the Society's affairs during the past year, during which a number of suggestions were advanced, including a request that notices of forthcoming B.I.S. meetings should appear in each issue of the *Journal*.

Following the conclusion of the main business, Mr. A. C. Clarke gave an address on "Flying Saucers."

At the Council Meeting on December 12, Dr. L. R. Shepherd was elected Chairman of the Society for 1953/4, and Mr. D. J. Cashmore was co-opted as an additional member of the Council to hold office in place of Mr. H. E. Ross.

Outside Lectures in the London Area

A considerable number of requests for lecturers by Youth Clubs and social organizations of all types in the London area cannot be accepted owing to a shortage of suitable speakers, and an appeal is therefore made for additional assistance from Fellows, who may be willing to give an occasional talk to such organizations.

The acceptance of any particular lecture is entirely a matter for the individual concerned, and inclusion in the Society's Lecture Panel does not involve any obligation.

Lecture Notes have been circulated to all members with the September, 1953 *Journal*, and copies of the Society's film strip are also now generally available (price 10s. per print).

Lectures to the type of organization referred to are usually of a non-technical nature, and do not normally carry a fee, though expenses are generally refunded, if desired.

Fifth International Astronautical Congress

The Fifth International Astronautical Congress will be held at Innsbruck, Austria, from August 1 to 7, 1954.

As in previous years, a reception will take place on August 1, while the two following days will be devoted to the business sessions.

August 4 will be reserved for an excursion into the country, and scientific lectures will follow on the 5th, 6th and 7th respectively, probably in two parallel courses, at the University of Innsbruck.

Members who wish to attend the Congress are asked to notify the B.I.S. Secretary as soon as possible.

Reservations may be arranged through the O.G.f.W., P.O. Box 192, Wien, V11/62, Austria.

Visit to an Observatory

Members who would like an opportunity of looking through a telescope are reminded of Mr. P. A. Moore's kind offer to make his 12-in. reflector available for this purpose, and interested members should write direct to Mr. Moore at "Glencathara," Worsted Lane, East Grinstead, Sussex. (*Tel.* East Grinstead 322.)

Branch Bye-Laws

The Council's Bye-Laws in relation to Branches have been examined by a special Bye-Laws Committee, and final recommendations were approved at the Council Meeting held on December 12, 1953, at which Branch Representatives were invited.

Arising from this revision, the existing Branch Bye-Law numbered 33-36 (1950 *Annual Report*, pp. 379-380) and 1-18 (May, 1952 *Journal* (3), pp. 131-133) have been withdrawn and superseded by revised regulations numbered 33-64 and 68 inclusive.

The Bye-Laws at present numbered 37-40 in the 1950 *Annual Report* have accordingly now been renumbered 64-67, in order to follow the revised Branch Bye-Laws.

Copies of the new Branch Bye-Laws are being distributed to all members concerned with the conduct of local Branch affairs.

Amendment to Bye-Law 1

At a recent meeting of the Council it was resolved that Bye-Law 1 be amended by the deletion of the words *"when notice is given to members"* and the insertion instead of the following words *"of such Resolution."*

The purpose of this Resolution is to enable the Council to make amendments to the Bye-Laws effective as soon as they have been approved.

Midland Branch Exhibits.

The picture, reproduced by courtesy of the Editor of *The Birmingham Evening Despatch*, shows Mr. A. C. Rotherham, the Midlands Branch Secretary, explaining a V2/WAC Corporal model to some of the visitors.

Midlands Branch Exhibits

The Midlands Branch of the B.I.S., at the invitation of the organizers, exhibited in the Stratford-on-Avon Flower Show, an annual event, held last year on the July 23, 24 and 25.

Attendance was in the region of 14,000 and included a large number of overseas visitors, many of whom showed great interest in the B.I.S. exhibit.

The exhibit itself consisted of two parts. The larger part was the *Daily Express* collection of panels showing various aspects of Rocketry and Interplanetary Flight, as used by the North-Western Branch in an earlier exhibition. These were used to form a corridor surrounding the second part of the exhibit, the Midland Branch stand, which included several paintings, charts, photographs, and scale models of rockets, both of existing and possible future types.

The central item of the exhibit was a box, on the upper surface of which was printed twelve basic questions on the subjects of Rocket Propulsion Interplanetary Flight, and Astronomy. Opposite each question were three holes corresponding with three answers, only one of which was correct for each question. Pushing a peg into the hole opposite the correct answer caused a bell to ring and a bulb to light up, a wrong answer being indicated by a buzzer. This item proved to be very popular and was in almost continuous use, serving

the double purpose of imparting basic facts to the users and saving the hard-worked throats of those members on duty.

B.I.S. literature and entry forms were in great demand throughout the three days of the exhibition.

The exhibit received a number of mentions in Midland newspapers.

Bristol Group

The remaining meetings of the Bristol Group this session will be held at "The Folk House," College Green, Bristol.

The Annual Business Meeting and a "Brains Trust" will be held at 7.30 p.m. at The Grand Hotel, Bristol, on Saturday, May 15, 1954.

London Film Show, April 3, 1954

The date for the film programme has now been fixed for April 3, 1954, and we are pleased to announce that it will again take place in the Lecture Hall of the Science Museum, South Kensington, by courtesy of the Director. Arrangements have been made for two showings, one at 10.30 a.m. and the other at 6 p.m.

The programmes will be as follows:—

10.30 a.m.—"Rocket Flight."
6.00 p.m.—(*a*) "The Viking Rocket."
(*b*) "Rocket Instrumentation."
(*c*) "High Altitude Research."

Admission is by ticket only; all applications should be addressed to the B.I.S. Secretary, at 12, Bessborough Gardens, London, S.W.1, accompanied by a stamped addressed envelope, and stating for which performance the ticket is required. We regret that accommodation limitations make it necessary to restrict the number of guest tickets to one per Member.

Glasgow Meetings

A preliminary meeting to discuss the formation of a Scottish Branch of the B.I.S. was held at the Glasgow Art Gallery and Museum, Kelvingrove, Glasgow, C.3, on December 13, 1953, which was followed by a further general meeting on January 17, when the B.I.S. Secretary, Mr. L. J. Carter, gave a short talk on the history and development of the astronautical movement. This was followed by a short film show.

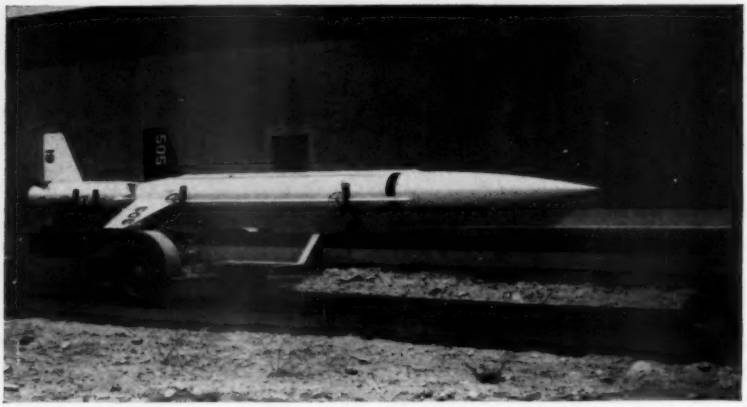
After the general meeting, a business meeting was held to discuss various matters concerning the formation of a Branch and a possible future lecture programme, possibly including some in Edinburgh.

Members interested in further particulars of meetings of a Scottish Branch are asked to communicate with Mr. P. H. Tanner, Provisional Branch Secretary, at the Glasgow Art Gallery and Museum.

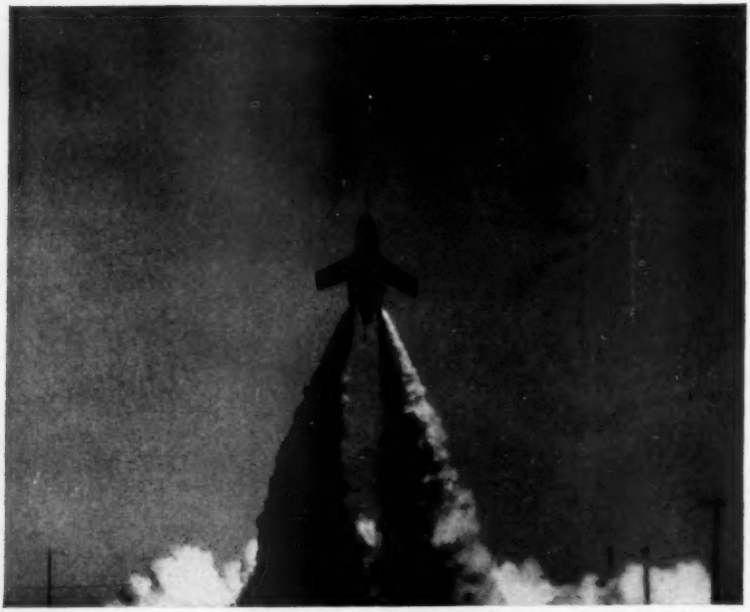
Epitaph Near Moonport

He got off in mid-passage, did Sandy MacPhee.
He'd be damned if he'd pay for a fall that was free.

(The Magazine of Fantasy and Science Fiction.)



Aerobee with Booster on Handling Trailer.



Regulus guided missile.

NOTES AND NEWS

The "Aerobee" Sounding Rocket

The "Aerobee" is a free-flight fixed-fin-stabilized sounding rocket, designed and manufactured by the Aerojet-General Corporation, Azusa, California, and is used primarily as a vehicle to transport scientific instrumentation in nearly vertical flights. It is capable of reaching an altitude of over 400,000 ft. with the nominal payload of 150 lb.

Launchings have been conducted by the U.S. Army, Navy, and Air Force from White Sands Proving Ground, Holloman Air Force Base, and from the U.SS. *Norton Sound* off the coast of Peru and in the Gulf of Alaska.

By making it possible to investigate the upper atmosphere, its temperature, composition, density, magnetic field, cosmic-ray intensity, X-ray intensity, winds, etc., the "Aerobee" has provided a medium for obtaining valuable scientific data previously unavailable. Since the initial launching in 1947, the "Aerobee" has been the most widely used and the least expensive research sounding vehicle in production. It is well known for its reliability and simplicity of design and operation.

The "Aerobee" vehicle is powered by a bi-propellant (nitric acid and aniline) liquid rocket, and it is initially accelerated by a large JATO booster rocket, which detaches and falls away upon cessation of booster thrust. Helium pressure is applied to the vehicle propellant tanks to cause the propellants to flow into the thrust chamber for combustion. The JATO booster is electrically ignited from a control room at the time of launching. After reaching a high velocity during powered flight, the "Aerobee" then coasts with decreasing velocities to the zenith altitude, where nose ejection may be accomplished for parachute recovery of instruments.

The "Aerobee" vehicle is 20 ft. long and 15 in. in diameter. The JATO booster which is used for launching adds another 6 ft. to the overall length. Welded construction is used throughout. The main body is an integrally welded stainless-steel tank assembly. The pressure tank, which contains helium for expulsion ot the liquid propellants, is located at the forward end of the assembly. A rolled-up steel skirt is welded to the forward end of the pressure tank for attachment of the nose section. On the aft end of the pressure tank, a rolled-sheet cylindrical section for oxidizer storage is welded. Separated only by a thin formed head, the fuel barrel of rolled sheet is welded directly to the oxidizer tank.

Rolled and welded construction is also used for the nose skin, which is then spun to an ogival shape to house the payload. A cylindrical extension is frequently used for added payload volume. The extension consists of a rolled sheet which is welded to attachment castings. The fins are produced by welding the edges of sheet metal over a plug. The plug is then removed and spars are installed for necessary reinforcement. The rocket thrust chamber is also fabricated by assembly of welded components.

Launching is accomplished from a tower approximately 150 ft. in height. The tower is required for guidance in the initial period, until the velocity is sufficient for the fins to provide aerodymanic stability. The launching towers

in New Mexico were both designed and erected by the Aerojet-General Corporation. The towers are provided with a tilting mechanism which permits compensating for observed winds in order to keep the vehicle within the limits of the test range, thereby permitting launchings under various wind conditions.

Experimental data are sometimes recorded in flight, and the records are recovered by parachute. In other flights, the test results are transmitted by radio from the "Aerobee" and recorded on the ground. Approximately 6 cu. ft. of space is available for the instrumentation in the hermetically-sealed nose compartment.

From the World's Press

The Tokyo *Japan News* of July 30 reported the projected inauguration of a Japanese interplanetary society. S. Chang, the writer of the announcement, says: "By a happy coincidence . . . the man now striving to found JAS is a famous science commentator with a nation-wide group of readers, Mr. Mitsuo Harada. In May this year he founded a committee for the creation of the Japan Astronautical Society, enlisting about 40 of Japan's glittering names in the fields of astronomy, technology, electronics, aeronautics and journalism. Among them are: Dr. I. Yamamoto, Japan's most famous astronomer, Prof. J. Nishiwaki, a technological expert of Tokyo University, and Prof. T. Asada, of Osaka University, an applied science authority, who won fame as Japan's first "rainmaker."

The paper quotes Mr. Harada as having said that one of the basic purposes of the organization "is to tell the public of the significance of each of the steps made by man for realizing his centuries-old dream of journeying to the Moon. By doing so, however, we aim at inducing the public to turn their eyes skywards, promote their knowledge of astronomy, realize man's place in relation to the universe—and inculcate in them a more accurate view of life."

Incidentally, the *Japan News* (which is printed in English) was one of the papers which, during July, published the Robert Chapman series of interplanetary articles, including the last, by our Secretary, L. J. Carter.

* * * * * *

A cutting from the *Daily Telegraph* of September 25 says that the R.A.F. is to be more closely associated with the design development of guided missiles and a new post is to be established for a senior R.A.F. officer in the Ministry of Supply. This follows from the announcement by Earl Alexander, Minister of Defence, in the House of Lords on April 15, that the R.A.F. will be responsible for the manning and operation of ground-to-air weapons. The cutting, quoting the Ministry of Supply, adds that although the technical qualifications of several R.A.F. officers are being considered, neither the title of the post nor the officer to fill it has been decided.

* * * * * *

Two American companies have recently released information about new heat-resisting paints which can be used in rocket motors. One is the Ideal Chemical Company's "Flamemastic"—the other, "Pyrolock," has been

developed by the B. F. Goodrich Company. According to *Chemical Week* (N.Y.) of August 22, "Pyrolock" is a sprayable water-base inorganic mastic which, at a cost of about $5·05/gal., can be applied directly to clean metal surfaces without sandblasting or priming surface preparations. A photograph in the *New York Herald Tribune* of August 6 shows the inventor, Donald V. Sarbach, demonstrating the coating with a 5,000° F. (2,760° C.) torch flame against two steel panels, one of which had been treated with Pyrolock, the other not. The untreated panel burned through in less than a second; that treated with Pyrolock remained undamaged after 4½ seconds. However, according to *Chemical Week* the material (which is available in tan colour only) is regarded more as an insulator than a flame protectant. It is interesting to note that the hulls of very high-speed aircraft, such as the "Skyrocket," reach high temperature and have to be repainted after each flight. The development of a durable heat-resisting white paint for such vehicles, and ultimately for spaceships, is then, a matter of no small importance.

* * * * *

An interesting article by Paul B. Stewart and Frank Kreith of the University of California, Berkeley, appeared in the September issue of *Chemical Engineering* (N.Y.). Here the writers discuss various possible uses of jet and rocket motors for industrial appliances, such as compression and evacuation jet pumps, and for industrial processes such as the thermal fixation of nitrogen and the partial combustion of oil for carbon black. As regards the former, the writers say, "Two different arrangements of components seem to be naturals for a reaction motor jet pump. The first ot these basic arrangements is patterned on steam-ejector practice. It consists of a jet pump with the reaction motor outside the pump unit. The exhaust or tail pipe of the engine is connected by piping to a nozzle ahead of the throat of the venturi section of the pump."

In the second case the whole of the reaction motor, most likely a true rocket engine, would be inside the pump. The article states that studies are now under way to develop package units of solid propellant thrust chambers for use in starting and stopping heavy machinery such as motors and turbines. The figures given for one such proposed unit are:—240 h.p. at 2,500 r.p.m. for about 20 seconds; total weight empty 50 lb., with the cartridge weighing an additional 100 lb.

In the field of industrial processing, the writers mention that Experiment Inc. has developed a ramjet type of reactor for the manufacture of ethylene and acetylene from hydrocarbon fuels. "This Company's patents" (says the article), "have been assigned to the Chemical Construction Co. and further intensive development work is under way."

The writers conclude with a description of the Linde Air Product Company's jet piercing blowpipe for drilling shot holes in taconite mining operations, as follows:—

> ". . . the JPM (jet piercing machine) is a self-propelled machine with a drilling rig similar to oil drilling equipment. Instead of the familiar rotary drill the machine uses a combustion chamber burning a hydrocarbon fuel with oxygen at 100 to 200 p.s.i. The three flames, raised to supersonic

velocity by nozzles, impinge on the rock causing it to crumble in the 4,000 deg. temperature. Water, used for cooling the combustion chamber, is also squirted out of the cutting head and vaporized. The combustion gas-steam mixture transports the rock powder out of the hole."

* * * * *

Several papers of about September 10, including the *Irish News*, the *Cork Examiner* and the *Montreal Gazette*, carried the news that Dr. Jack E. Myers of the University of Texas has been asked by the U.S. Air Force's department of space medicine "to explore the possibilities of using algae as a source of oxygen for space navigators."

The reports cite Dr. Myers as "one of the leading U.S. researchers on techniques designed to exploit algae—tiny plants which occur naturally in ponds and other bodies of water—as a potentially rich source of protein for food and for industrial and medicinal purposes."

Dr. Myers is quoted as saying that preliminary calculations for incorporating such a system in a spaceship "look rather formidable." "The biggest problem," he said, "would be providing a source of artificial sunlight capable of stimulating the growth of the plants—and hence release of oxygen—without being prohibitive in size."

We ourselves would like to remark that algae—or any plant for that matter—are not, strictly speaking, *sources* of oxygen . . . in fact they use it. Only when illuminated do they yield up more oxygen than they retain. This means that unless 100 per cent. reclamation of waste products, and the plants themselves, is made possible, some new oxygen has to be introduced into the cycle.

All things considered, it seems probable that for space flights of short duration the equipment needed for algae operation may well to be too bulky and weighty; however, in the case of very protracted journeys such a system may prove practical.

Readers will recall the two articles on this subject by N. J. Bowman which appeared in the May and July issues of this *Journal*. An earlier note under the title "*Green Plants as Atmosphere Regenerators*," written by H. E. Ross, was published in the January, 1947 *Bulletin* of this Society.

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We have to thank Professor A. M. Low for awakening the interest of Irish newspapers in the possibilities of interplanetary flight. In a broadcast from London to Turkey in mid-September he said that although the first spaceship would probably be built by the Americans, he felt sure that an Irishman would be numbered among the crew, and might indeed "plant the first flag on the Moon."

Asked by the *Irish Press* of Dublin, why he said this, Professor Low replied that as he had a good shot of Irish blood in him from his maternal grandmother, he had studied Irishmen and found them always more interested in adventure than in money. "Ireland," he added, "has provided the world with great thinkers, scientists and soldiers out of all proportion to her size."

Thus fired with patriotic fervour, the *Irish Press* ran a series of interplanetary

articles early in October. Delving deep into history, and under the headline "Did British learn from an informer?" they discovered that the Irish patriot Robert Emmet was the first European to grasp the worth of the rocket—as a weapon for use in his rising against the hated and deplorably un-Irish English. Unfortunately—or perhaps fortunately—Emmet's rocket depot at Patrick Street blew up; an incident which the article rather naively and certainly ambiguously says "must have taught them (the English) something."

Apparently one of Emmet's men, Finnerty by name, "turned informer and later was employed in Woolwich Arsenal." This was just before Congreve evolved the war rockets associated with his name, and the article adds that the historian Madden supposes that Finnerty sold the secrets of rocket making to Congreve.

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Professor Oliphant, Director of the School of Physical Sciences at the Australian National University, Canberra, is quoted as saying that the world's most powerful nuclear accelerator is being built at the University. According to the *Nottingham Guardian* of June 24, the new accelerator will produce particles imbued with energies in excess of 10,000 million electron volts—four times greater than those furnished by the accelerator at Brookhaven Laboratories, U.S.A., which is said to be the most powerful accelerator at present in operation.

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The London *Times* and *Daily Express* of July 17 and August 4 respectively, note further reports of Russian rocket work. The *Daily Express* quotes Mr. George P. Sutton, a leading U.S. rocket engineer, as saying that the Russians have built a 2-stage, 80-ton, "super V2," with a range of more than 1,800 miles. The *Times*, quoting the American monthly magazine *Aviation Age*, says: "mass production methods enable the Russians to produce 24,000 supersonic missiles of an improved V2 pattern a year. This information is attributed to "a German engineer who recently escaped from Russia." It is further remarked that with German technical aid rocket launching has been perfected to a point where a single launching ramp can fire missiles at the rate of 800 an hour. A 97-ton multistage rocket with a range of 2,500 miles is also said to be in course of development.

If these persistent reports are true, then one must agree with the concluding remark by *Aviation Age* quoted by the *Times*, which says: "the overall impression of Soviet work in guided missiles is one of immense effort and considerable achievement."

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According to the *New York Herald Tribune* of July 1, tonnage-scale output of hydrazine has been made possible by completion of Mathieson Chemical Corporation's new facilities at Lake Charles, La. It is said that $3,000,000 has been invested in the scheme. The account goes on to say that apart from its use as a rocket propellant "Hydrazine has already found use in the manufacture of drugs, photographic chemicals, soldering fluxes, foam rubber, insecticides, plant-growth regulators, metal-plating materials, boiler compounds

and other chemical products . . . . In the drug field it has already emerged as one of the basic ingredients of compounds for treatment of tuberculosis" . . . in addition to which, "it has promise in preparation of hormones, antihistamines, antibiotics, vitamins and sulfa drugs."

This is one more piece of evidence supporting the view that progress in rocketry can contribute to human welfare.

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Air Vice-Marshal G. Harcourt-Smith, U.K. Chief Service Liaison Officer in Australia, is reported as having said that Australia might be the most suitable place from which to launch a trip to the planets. All man needed to accomplish this was a "continuance of the spirit which enabled our forefathers to conquer the sea." Technical skill would do the rest, he added.

Similar confidence in astronautics was expressed by Lord Nelson, speaking in Dublin at Armagh Observatory, following a talk entitled "There may be life on Mars."

A cutting from the *Northern Whig* (Belfast) of June 6 quotes Lord Nelson as remarking: "Interplanetary travel . . . will come in the future, and if atomic energy could be harnessed to propel space-ships, very extraordinary developments might come about, perhaps much sooner than anyone thought."

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Press comments on Zurich have been many, varied, and in some cases lurid. Generally speaking, the concensus of opinion seems to be that astronautics is sheer fantasy—but inevitable. We agree with that. It is not our fault that astronautics rocks the imagination—like its ultimate achievement, that is "inevitable." We would, however, plead for a little more understanding of astronautical aims. John Hillaby, writing in the *Spectator* of August 21, is not at all sure whether astronauts are "Good Guys" or "Space Rats." . . . Well, Mr. Hillaby, let us assure you that our intentions are honourable, but in any case, wars will not be stopped by prohibiting rocketry and astronautics. The problem is much more fundamental. It goes right back to ordinary people's behaviour one to another.

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The Washington *Chemical and Engineering News* of April 13 notes that a lithium-magnesium alloy one-quarter the weight of steel has been developed by the Bureau of Mines. A sample rod 4 in. long was exhibited at the International Magnesium Exposition but it is thought that a year will elapse before technical information about this new product will be released. The paper says: "One possible use for the alloy is in handling lithium, for which it may be well suited especially from the standpoint of pressure and impact. Lithium as a fuel produces one of the highest exhaust velocities known, aside from that achieved by atomic fuels. If the alloy is destined to handle lithium, it may be part of the first rocket to reach the Moon."

ABSTRACTS

Edited by J. HUMPHRIES

Abbreviations of titles of journals were given in the May, 1950 issue of the *Journal*, and addenda have appeared in subsequent issues. The following is a further addendum to the list:—

Bull. Amer. Math. Soc.	Bulletin of the American Mathematical Society.
Bull. Amer. Phys. Soc.	Bulletin of the American Physical Society.
Mém. Poudr.	Mémorial des Poudres.
R.A.F. Flying Rev.	Royal Air Force Flying Review.
Tech. Mod.	La Technique Moderne.

Many of the Abstracts noted are available on loan to members resident in the British Isles. Requests should be addressed to J. Humphries, 97, Churchill Avenue, Southcourt, Aylesbury, Bucks.

AIRCRAFT

(36) **Supersonic flight in the Soviet Union.** *Interavia*, **8**, 256-257. (*May*, 1953.) Description of development work on German DFS 346 rocket-propelled aircraft.

(37) **High-speed research airplanes.** W. T. BONNEY. *Sci. Amer.*, **189** (4), 36-41 (*Oct.*, 1953). Review of supersonic flight work being carried out by N.A.C.A.

ASTRONAUTICS

(See also Abs. Nos. 109, 131 and 135.)

(38) **Discussion of the elements of astronautics.** Q. MAJORANA. *Coelum*, **20**, 3-4, 33-42 (1952) (*In Italian*). Physical basis of space-flight.

(39) **The Third International Congress for Astronautics.** *Weltraumfahrt* (4), 99-101 (*Oct.*, 1952) (*In German*). General review of proceedings.

(40) **The exhibition "Rockets and Space-flight."** *Weltraumfahrt* (4), 104-105 (*Oct.* 1952 (*In German*). Description of exhibition held during 3rd International Astronautical Congress, Stuttgart, 1952.

(41) **Space-flight research.** E. SÄNGER. *Weltraumfahrt* (4), 97-98 (*Oct.*, 1952) (*In German*). Address delivered at 3rd International Astronautical Congress, Stuttgart, 1952.

(42) **The possibility of changing from an elliptical path to a circular path and vice versa.** Pt. II. W. SCHAUB. *Weltraumfahrt* (4), 106-111 (*Oct.*, 1952) (*In German*) Theoretical study.

(43) **Inertial forces in the Earth-Moon field: calculation and construction of orbits for space-ships.** B. THÜRING. *Weltraumfahrt* (4), 112-115 (*Oct.*, 1952) (*In German*). Discusses forces acting and proposes a numerical and a graphical method for orbital determination.

(44) **The development position at the present day. A report on the 3rd International Astronautical Congress from September 1 to 6, 1952, in Stuttgart.** H. W. HAHNEMANN. *Z. Ver. dtsch. Ing.* [*V.D.I.*], **94**, 1045-1048 (*Nov.* 11, 1952) (*In German*) (11 *refs.*).

(45) **Is space-flight possible?** H. H. KÖLLE. *Z. Ver. dtsch. Ing.* [*V.D.I.*), **94**, 1042-1044 (*Nov.* 11, 1952) (*In German*). Review of the 2nd International Astronautical Congress in London, 1951.

(46) **Attack on the third dimension.** W. LEY. *Sky and Telescope*, **12** (3), 58 (1953). Problems of space-flight.

(47) **Historical aspects of interplanetary flight.** G. NEBBIA. *Coelum*, **21** (1-2), 6-10 (1953) (*In Italian*). History of rockets since V2.

(48) **German spaceship.** *R.A.F. Flying Rev.*, **8** (8), 16-17 (*May*, 1953). Description of Satellite Rocket 52 designed by Hoeppner.

(49) **The Fourth International Astronautical Congress.** E. BURGESS. *Aircraft Engng.*, **25**, 312-314 (*Oct.*, 1953). Summaries of a selection of the papers read at the Zurich Congress.

ASTRONOMY

(50) **Mars.** G. DE VAUCOULEURS. *Sci. Amer.*, **188,** 65-73 (*May*, 1953). General review of present-day knowledge.

(51) **Our nearest neighbour, the star Alpha Centauri.** BARBIER-BROSSAT. *Astronomie*, **67,** 287-292 (*July*, 1953 (*In French*). Comprehensive account.

(52) **The transit of Mercury of November 14, 1953.** J. T. CARLE. *Strolling Astronomer*, **7,** 121-124 (*Aug.*, 1953). Discussion of the present and past transits with relevant remarks upon such topics as Mercury's atmosphere.

(53) **Photography of the canals of Mars.** E. PETTIT. *Publ. Astr. Soc. Pacif.*, **65,** 197-201 (*Aug.*, 1953). General notes on photographing the Martian canals.

(54) **Ultraviolet spectral radiant energy reflected from the Moon.** R. STAIR and R. JOHNSTON. *J. Res. Nat. Bur. Stand., Wash.*, **51** (2), 81-84 (*Aug.*, 1953). Results of measurements given. Concludes that there is a possibility of a lunar reflecting surface similar to that of powdered glassy silicates (31 *refs.*).

(55) **Transits of Mercury.** A. P. FITZGERALD. *Irish Astr. J.*, **2,** 203-209 (*Sept.*, 1953).

(56) **Papers on the study of lunar meteoric phenomena.** *Documentation des Observateurs*, Bull. 11 (*Nov.*, 1953) (*In French*). Recent French investigations, including an article on Leonid and Geminid lunar meteors.

ATMOSPHERE

(See also Abs. No. 94)

(57) **Ionospheric and upper air research.** *Physics Today*, **6** (3), 10-13 (*March*, 1953). Review of work being carried out by the U.S. Air Force, Cambridge Research Centre.

(58) **Synoptic rocket observations of the upper atmosphere.** S. F. SINGER. *Nature*, **171,** 1108-1109 (*June* 20, 1953). Suggestion to use aircraft to launch small sounding rockets thus increasing their ceiling. Cost would be low (£300/rocket) and a long recording time (*c.* 90 secs.) would be obtainable in the 70 to 80 km. region.

(59) **Moby Dick balloons explore upper air.** *Aviation Wk.*, **59** (8), 28-30 (*Aug.* 24, 1953). These balloons are aimed at a thorough exploration of the upper atmosphere between 50,000 and 100,000 ft. as a preliminary to piloted flight in this region and beyond. They vary in diameter from 50 to 116 ft. and can carry up to 500 lb. pay-load and stay aloft for three days at an altitude that can be controlled within 2,000 ft. More than 160 balloons have been launched since 1950 and more than 90 per cent. of flying saucer reports coincide with the time and place of these reports.

(60) **The high altitude sounding rocket.** M. W. ROSEN and R. B. SNODGRASS. *Aero. Dig.*, **67** (3), 90, 92-99 (*Sept.*, 1953). Early history of the rocket motor and review of U.S. postwar sounding programme.

(61) **Rocket exploration of the upper atmosphere.** E. BURGESS. *Aircraft Engng.*, **25,** 307-308, 316 (*Oct.*, 1953). Report on the Conference on Upper Atmosphere Research by Rocket held in Oxford, Aug. 24-26.

(62) **V2 rocket in upper atmosphere research.** C. F. GREEN. *Aero. Dig.*, **67** (5), 20-26 (*Nov.*, 1953). Review of U.S. research programme during which 66 V2's were launched, 32 of which were completely successful.

BIOLOGY AND MEDICINE

(63) **Physics and physiology of pressure drops in space.** F. HABER and H. STRUGHOLD. *Weltraumfahrt* (4), 118-120 (*Oct.*, 1952) (*In German*). The effect of a leak in a spaceship on the condition of the atmosphere and on the occupants.

(64) **Food from algae.** H. Gaffron. *Research*, **6,** 222-230 (*June*, 1953). Review of the possibilities of using unicellular algae as a supplementary source of food. The space requirement is small compared with conventional food sources.

(65) **Is man alone in space?** L. C. EISELEY. *Sci. Amer.*, **189,** 80-82, 84, 86 (*July*, 1953). Review of factors leading to Man's development. Concludes that it is unlikely that similar life-forms have developed in the Universe.

(66) **Life on other worlds.** W. R. THORSON. *Griffith Observer*, **17,** 116-119 (*Oct.*, 1953). General discussion with attention paid to the adaptability of life.

CHEMISTRY

(67) **Explosive properties of hydrogen peroxide.** L. MEDARD. *Mém. Poudr.*, **31**, 273-285 (1949) (*In French*). Hydrogen peroxide detonates readily in the pure state, but will not detonate in aqueous solutions containing less than 94 per cent. although aqueous solutions will decompose explosively under catalytic influence. Heat of explosion at constant volume is 24·6 kcal./mole.

(68) **Explosive characteristics of hydrogen peroxide vapour.** C. N. SATTERFIELD, G. M. KAVANAGH and H. RESNICK. *Industr. Engng. Chem.*, **43**, 2507-2514 (*Nov.*, 1951). At atmospheric pressure vapours containing 26·0 mole. per cent. or more hydrogen peroxide can be exploded by initiation with hot wire or glow plug. Explosive limits are given (13 *refs.*).

(69) **High-speed chemistry.** L. P. LESSING. *Sci. Amer.*, **188**, 29-35 (*May*, 1953). Method of study of extremely fast reactions in flame fronts.

(70) **Hydrazine.** L. P. LESSING. *Sci Amer.*, **189**, 30-33 (*July*, 1953). The production of hydrazine by the Raschig process, its properties and uses.

MATERIALS

(71) **Evaluation of plastics for liquid propellant rocket applications.** TERLIZZI and LENEHAN. *Modern Plastics*, **30** (6), 140, 142, 144, 146, 223 (*Feb.*, 1953). Testing techniques for plastics intended for use with nitric acid. Plastics are used for expellant bags and coatings for storage purposes. One important problem is diffusion through plastic. Storage for nine months to a year is required for anti-aircraft rockets.

(72) **Materials for rocket combustion chambers.** H. G. MEBUS. *Interavia*, **8**, 266-267 (*May*, 1953). Discusses various materials for use in cooled chambers and concludes that tungsten is best.

MISCELLANEOUS

(73) **Günter Loeser.** *Weltraumfahrt* (4), 122-123 (*Oct.*, 1952) (*In German*). Biography.

PHYSICS

(See also Abs. Nos. 105, 117 and 118)

(74) **Heat transfer in turbulent shear flow.** W. D. RANNIE. C.I.T., thesis (*June*, 1951).

(75) **Thermodynamic functions of polyelectric atoms at very high temperatures.** R. V. MEGHREBLIAN. C.I.T., thesis, (1952).

(76) **Relaxation time for energy exchanges in burning gases.** J. SURUGUE, R. KLING and R. HUCHET. *Rech. Aérodyn.* (31), 25-29 (*Jan.-Feb.*, 1953 (*In French*). Importance in rocket motors noted and method of measurement described. Pierce's interferometer method discussed at length.

(77) **Where do cosmic rays come from?** A. BEISER. *Sci. Mon.*, **77**, 76-79 (*Aug.*, 1953). Popular account of present state of knowledge.

(78) **Viscosity of nitrogen dioxide in the liquid phase.** G. N. RICHTER, H. H. REAMER and B. H. SAGE. *Industr. Engng. Chem.*, **45**, 2117-2119 (*Sept.*, 1953). Data from 40° to 280° F. at pressures up to 4,600 lb./sq. in. abs (19 *refs.*).

(79) **Condensed gas calorimetry. V.**—Heat capacities, latent heats and entropies of fluorine from 13 to 85° K; heats of transition, fusion, vaporization and vapour pressures of the liquid. J.-H. HU, D. WHITE and H. L. JOHNSTON. *J. Amer. Chem. Soc.*, **75**, 5642-5645 (*Nov.* 20, 1953) (12 *refs.*).

PROJECTILES

(80) **Stalking the missile.** D. REUYL and L. G. DE BEY. *Ordnance*, **36**, 237-241 (*Sept.-Oct.*, 1951). Instruments used for tracking long-range rockets.

(81) **Extension of the rocket station, Florida.** *Weltraumfahrt* (4), 103 (*Oct.*, 1952) (*In German*). Present range is 320 km. long and is to be extended to over 1,600 km. If necessary the range could be extended to 15,000 km., over the Antarctic.

(82) **The smallest large rocket.** *Weltraumfahrt* (4), 116-117 (*Oct.*, 1952) (*In German*). Description of the 1/50 scale model V2, in production in Germany as a toy. Reaches 100 m. altitude and returns to Earth by parachute.

(83) **The indirect way to space-flight.** *Weltraumfahrt* (4), 121 (*Oct.*, 1952) (*In German*). Brief description of Martin Matador.

(84) **Inertial navigation system.** *Tele-Tech*, **53** (*Dec.*, 1952). A gyro-stabilized accelerometer senses all components of inertial forces and allows a pre-set course to be followed.

(85) **The guidance of rockets.** G. SIEGEL. *Z. Ver. dtsch. Ing.* [*V.D.I.*], **94**, 1193-1194 (*Dec.* 21, 1952) (*In German*). Brief discussion of guidance methods with special reference to A4.

(86) **Guided missile tests in 20 seconds.** T. L. GREENWOOD. *Instrumentation*, **6** (5) 12-15 (*Second quarter* 1953) [*Also* as **Missile testing at Huntsville.** *Aero. Dig.*, **67** (3), 22-26 (*Sept.*, 1953)] Research facilities and equipment at U.S. Army Ordnance Missile Labs., Huntsville.

(87) **Boeing rockets over Alamogordo.** *Interavia*, **8**, 238-239 (*May*, 1953). Photos. of the firing of a Boeing GAPA.

(88) **World guided missile trends.** M. M. DECKER. *Interavia*, **8**, 240-243 (*May*, 1953). Reviews trends of operational missiles with emphasis on ground-to-air and ground-to-ground types.

(89) **Robots join the Arsenal.** P. M. GALLOIS. *Interavia*, **8**, 231-237 (*May*, 1953). General review of guided missiles, their use and problems.

(90) **Induction generators for guided missiles.** E. D. LYTLE. *Interavia*, **8**, 268-269 (*May*, 1953). General design problems of small 400-cycle, 115/200-volt, 3-phase squirrel-cage generators.

(91) **Recent developments in foreign rockets and guided missiles.** N. J. BOWMAN. *J. Space Flight*, **5** (6), 1-4 (*June*, 1953). Review of post-war European developments.

(92) **Microsecond photography of rockets in flight.** E. BARKOFSKY, R. HOPKINS and S. DORSEY. *Electronics*, **26** (6), 142-147 (*June*, 1953). Electronically-controlled flash-lamps are used in connection with 46 precision ballistic cameras to provide up to 138 pairs of silhouette images of a rocket fired at sandbags in a 500-ft. indoor range, for the determination of aerodynamic and ballistic characteristics.

(93) **Vast missile programme pushed by Soviets.** *Aviation Age*, **20** (2), 24-26 (*Aug.*, 1953). List of missile installation and production centres given with data on various missiles.

(94) **Rockets aid cosmic-ray studies.** *Aviation Wk.*, **59** (11), 21 (*Sept.* 14, 1953). Photos. of Deacon project near North Pole.

(95) **Guided missiles for Britain's three fighting services.** *Discovery*, **14**, 326-327 (*Oct.*, 1953). Based on Ministry of Supply press releases.

RADIO AND ELECTRONICS

(See also Abs. Nos. 90 and 92)

(96) **Radio telemetry.** C. I. CUMMINGS and A. W. NEWBERRY. *J. Amer. Rocket Soc.* **23**, 141-145 (*May-June*, 1953). Discusses significant features of the more generally used systems together with an indication of future possibilities (15 *refs.*).

(97) **How electronics controls guided missiles.** J. M. CARROLL. *Electronics*, **26** (7), 130-136 (*July*, 1953). V2 guidance system.

(98) **Television monitors rocket engine flame.** F. A. FRISWOLD. *Electronics*, **26** (10), 187-189 (*Oct.*, 1953). Remote viewing can show when a rocket is not operating correctly. An industrial vidicon camera has given best results under the severe conditions of vibration and noise.

(99) **Telemetry for guided weapons.** *Engng.*, **176**, 518-519 (*Oct.* 23, 1953). Systems developed by Ministry of Supply are described. For measuring control-surface positions, strains, pressures and torques, a time multiplex system is used. This has 23 data transmission channels and has a frequency response up to 200-230 c.p.s. For measuring wave-forms in electronic equipment a pulse position modulation equipment is used, with 20 high-frequency channels. Both types may be installed in one missile and both are in quantity production.

(100) **Guided-weapons telemetering.** *Flight*, **64**, 556-558 (*Oct.* 23, 1953). The two systems devised by the Ministry of Supply and recently released are the time multiplex and pulse position modulation systems. In the time multiplex system each information channel is sampled in turn. In the P.P.M. system channel information is given by the time interval between the trailing edge of a reference pulse and the incidence of a one micro-second channel pulse. The two systems are fully described.

ROCKET MOTORS

(See also Abs.. Nos. 71, 72 and 98)

(101) **Utilization of energy in rocket motors.** M. Bouruard. *Tech. Mod.*, **43**, 305-307 (1951) (*In French*). Considers chemical processes in, and efficiencies of, rocket motors.

(102) **Adiabatic flame temperature in jet motors.** W. S. McEwan and S. Skolnik. *Industr. Engng. Chem.*, **43**, 2818-2822 (*Dec.*, 1951). Reviews several systematic procedures for evaluating rocket propellant combustion temperatures. Propellants with low enthalpies (about — 875 cal./gm.) yield flame temperatures which are essentially independent of pressure.

(103) **Geometrical relations for solid propellant charges for rocket motors.** E. W. Price. *Bull. Amer. Phys. Soc.*, **27** (6), 20 (1952).

(104) **The auxiliary rocket and its propellants.** J. T. Reynolds. *Aero France* (7-8), 130-132 (1952) (*In French*). Advantages and disadvantages, quoting the Armstrong Siddeley "Snarler" as an example.

(105) **Dependence of jet-tone eigen frequencies on aerodynamic and geometrical parameters involved.** L. E. Schilberg and A. B. C. Anderson. *Bull. Amer. Phys. Soc.*, **27** (6), 21 (1952). Experimental results.

(106) **Stability of flow in a bipropellant rocket motor.** S. Sherman. *Bull. Amer. Math. Soc.*, **58**, 196 (1952).

(107) **High-frequency combustion instability in rockets with distributed combustion.** L. Crocco and S.-I. Cheng. *Princeton Univ. Aeronautical Engng. Lab.*, 24 pp. (*Sept.*, 1952).

(108) **Air temperature near a rocket-motor exhaust flame.** W. W. Belwanz and F. E. Wyman. *Naval Res. Lab. Rep. No.* 4076, 7 pp. (*Nov.*, 1952).

(109) **The internal reaction engine.** J. R. Goodykoontz. *J. Amer. Soc. Naval Engrs.*, **65**, 97-99 (1953). Theoretical study and application to space-flight.

(110) **Instrumentation for rocket testing.** E. Cartotto. *Instruments*, **26**, 585-587 (*April*, 1953). Instrumentation techniques applicable to testing of rocket motors are presented, with emphasis on temperature, pressure, thrust, weight and propellant flow.

(111) **Pressure recorder for rocket-motor studies.** J. Alman. *Electronics*, **26** (5), 146-147 (*May*, 1953). A capacitor pickup responsive from vacuum to 30,000 p.s.i.g. over a frequency range from 0 to 110,000 c.p.s. is used with a frequency modulated oscillator. The system can also be used with other types of pick-up.

(112) **Combustion instability in an acid-heptane rocket with a pressurized-gas propellant pumping system.** A. O. Tischler and D. R. Bellman. *NACA Tech. Note* 2936, 50 pp. (*May*, 1953). Experimental results on 300 lb. thrust motor compared with theory. With L^* of 100 ins. and chamber pressure of 280 p.s.i.a. pressure fluctuation frequency was 38 c.p.s. compared with 37 c.p.s. predicted by assuming a monopropellant model and a combustion time delay. Increasing L^* decreased the frequency. Increasing the chamber pressure or the injector pressure drop increased the frequency.

(113) **Sampling and analysis of combustion gases.** J. L. Beal and J. T. Grey. *J. Amer. Rocket Soc.*, **23**, 174-177 (*May-June*, 1953). Rapid cooling of samples in order to "freeze" the high-temperature composition is discussed. Small diameter sampling probes using expansion, dilution by inert gas and cooling from the tube wall have produced satisfactory cooling in a few microseconds. Methods of gas analysis are also compared (17 *refs.*).

(114) **Reduction of rocket-motor performance data by means of I.B.M. computing machines.** C. M. Beighley and T. E. Cheatham. *J. Amer. Rocket Soc.*, **23**, 150-154 (*May-June* 1953). A method for calculating experimental rocket-motor performance and heat transfer data on I.B.M. machines is described together with an approximate time study and cost analysis.

(115) **Methods of measuring thrust.** J. A. BIERLEIN and K. SCHELLER. *J. Amer. Rocket Soc.*, **23**, 128-132 (*May-June*, 1953). Principles of various methods are reviewed. Methods of measuring varying thrusts also discussed and elements of thrust stands indicating their areas of utility.

(116) **Photographic techniques in jet propulsion studies.** K. BERMAN and E. H. SCHARRES. *J. Amer. Rocket Soc.*, **23**, 170-173 (*May-June*, 1953). Motion picture cameras are classified into five categories depending on frame frequency or linear film speed. Methods of application to testing and systems for correlating and interpreting results are discussed (41 *refs.*).

(117) **Optical methods for the determination of combustion temperatures.** P. J. DYNE and S. S. PENNER. *J. Amer. Rocket Soc.*, **23**, 165-169 (*May-June*, 1953). Brief survey giving basic principles of each technique and experimental arrangement (31 *refs.*).

(118) **The measurement of gas temperature by immersion-type instruments.** E. F. FIOCH and A. I. DAHL. *J. Amer. Rocket Soc.*, **23**, 155-164 (*May-June*, 1953). Discusses characteristics, together with ranges of applicability and methods of construction for base, sheathed, shielded and aspirated thermocouples, for resistance-type elements and for several pneumatic or thermodynamic systems (18 *refs.*).

(119) **Methods of flow measurement.** J. GREY and F. E. LIU. *J. Amer. Rocket Soc.*, **23**, 133-140 (*May-June*, 1953). Review of all types. Differential pressure meters are not suitable for fluctuating flows and volumetric type require knowledge of fluid density before mass flow can be deduced. The only true mass flow meter available commercially is one depending on the measurement of the angular momentum of a rotating fluid passage (30 *refs.*).

(120) **Recording instruments in rocket and jet engine testing.** H. B. JONES. *J. Amer. Rocket Soc.*, **23**, 146-149 (*May-June*, 1953). Mechanical recorders, self-balancing potentiometers, magnetic oscillographs, cathode-ray oscillographs and magnetic tape recorders are discussed and compared with respect to response time, accuracy, flexibility, ease of maintenance and cost. Emphasis is placed on tape recording.

(121) **Dynamic pressure measuring systems for jet propulsion research.** Y. T. LI. *J. Amer. Rocket Soc.*, **23**, 124-127, 145 (*May-June*, 1953). To measure frequencies between 100 and 2,000 c.p.s. the pressure indicator should have a natural frequency above 10,000 c.p.s. The indicator should also be able to dissipate heat at a rate of 10 B.T.U./in.^{2}/sec. and its performance must be relatively independent of temperature. Two types of water-cooled diaphragm are discussed in detail and it is concluded that the strain-gauge indicator is the best (11 *refs.*).

(122) **Flow at constant volume.** H. SCHENK. *J. Amer. Rocket Soc.*, **23**, 184 (*May-June*, 1953). Theoretical discussion of isovolumetric expansion.

(123) **Flow controls.** K. R. STEHLING and P. M. DIAMOND. *J. Amer. Rocket Soc.*, **23**, 178-183, 185 (*May-June*, 1953). Valve types are discussed in detail and other controls such as accumulators, cavitating venturis, calming chambers and flow-pulsing units are outlined.

(124) **Control system for a rocket motor.** Armstrong Siddeley Motors, Ltd. Brit. Pat. Spec. 694,371 (*July 22*, 1953). Complete layout for liquid propellant rocket motor.

(125) **Valve means for the supply of propellant to a rocket motor.** Armstrong Siddeley Motors, Ltd. Brit. Pat. Spec. 694,372 (*July 22*, 1953). Combined stop and throttle valve.

(126) **Ignition equipment for the combustion equipment of a rocket motor.** Armstrong Siddeley Motors, Ltd. Brit. Pat. Spec. 694,373 (*July 22*, 1953). Small pre-combustion chamber, using main propellants for ignition of main combustion chamber.

(127) **A.F. tests rocket engines in giant stands.** D. A. ANDERTON. *Aviation Wk.*, **59** (9), 24-26 (*Aug. 31*, 1953). Description of 500,000-lb. thrust test stand at Edward's Field, Calif.

(128) **Rocket motors for wind tunnels?** *Aviation Wk.*, **59** (11), 54 (*Sept. 14*, 1953). Proposed use of six 5,000-lb. thrust rocket motors, acting as ejectors to produce a 400 m.p.h. wind in a 4 ft. × 6 ft. test section.

ROCKET PROPELLANTS

(129) **Better rocket propellants—in perspective.** H. W. FLEMMING. *Chemiker-Zeitung*, **76**, 517-518 (1952) (*In German*). Possibility of using metal hydrides, in particular those of aluminium.

(130) **How should one describe the propellant mixture ratio?** U. T. Bödewadt. *Weltraumfahrt* (4), 123-127 (*Oct.*, 1952) (*In German*). Discussion of the various methods of quoting mixture ratio.

ROCKET PROPULSION

(See also Abs. No. 47)

(131) **Present-day knowledge of rocket propulsion.** G. Nebbia. *Coelum*, **19**, 9-10, 127-134 (1951) (*In Italian*) (78 *refs.*).

(132) **The advance of rocket science.** F. I. Ordway. *Sky and Telescope*, **132**, 297-298 (1952). Astronautical societies and the actual state of their research on rockets.

(133) **Rockets behind the Iron Curtain.** G. P. Sutton. *J. Amer. Rocket Soc.*, **23**, 186-191 (*May-June*, 1953). Reviews available literature and concludes that the U.S.S.R. has a large number of competent scientists on rocket development. Suggests that improved "Wasserfall" and "A4" rockets are in production and that work is well advanced on an auxiliary engine for aircraft and also a large motor of over 200,000 lb. thrust for long-range missile applications and finally for a satellite vehicle (33 *refs.*).

(134) **A.F. gets high-speed data from supersonic sleds.** D. A. Anderton. *Aviation Wk.*, **59** (10), 26-27, 30-32 (*Sept.* 7, 1953). Rocket-propelled sleds are used for aero-medical, flutter, aerodynamic and parachute studies. Liquid propellants are used since solids are 25 times as costly. A Mach. number of 2 can be reached with accelerations up to 50 g.

(135) **Military and civilian rocket research.** E. Burgess. *Engineer*, **196**, 581-583 (*Nov.* 6, 1953). Suggestion for setting up a research organization under UNESCO, aimed at achievement of space-flight. Lists types of research required.

REVIEWS

Flying Saucers Have Landed

(By D. Leslie and G. Adamski. T. Werner Laurie, London. 232 pp. 12s. 6d. net)

Readers of the *Journal* who have already seen this book may well wonder why we are bothering to review it in these pages. We do so partly to save other members from wasting their money—unless they happen to be particularly interested in psychopathology—but primarily because it has been so widely reported that some analysis seems necessary. It is an appalling comment on present-day journalism that even the *Observer* saw fit to consider this farrago of nonsense seriously, thereby influencing thousands of readers who might otherwise have treated it with the contempt it deserves.

The book is in two parts. Book One, by Desmond Leslie, is an incredible hodge-podge of "saucer" reports, going back to ancient oriental writings, and obviously the result of much reading. We hesitate to say "scholarship" in a book which cannot even get its short bibliography in alphabetical order, and which refers in one place to "Arthur Clark and Wily Lee" (though we did not let this prejudice us unduly). It must be admitted that many of the passages which Mr. Leslie has dug up from Indian religious writings are quite fascinating. If they prove one thing, it is that science-fiction has a more venerable antiquity than even its most devoted advocates imagined. No doubt some diligent reader in two or three thousand years' time, will employ Mr. Leslie's technique to prove, from ancient files of *Amazing Stories*, that the early twentieth century had spaceships, heat rays, antigravity and robots.

But let us leave these ancient writings and Mr. Leslie's comments upon

them, most of which will only interest those whose brains have already been addled by occultism. We are even prepared to grant the author's premise, which is that the persistence of such accounts down the ages proves that "saucers" have always been with us.

Coming to more modern times, there are lists of sightings, including many from contemporary newspapers, which at first make an impressive case. Some of these are undoubtedly "genuine"—unexplained—"saucers," but such indiscriminate listings are totally worthless without careful evaluation. Even from the scanty information Mr. Leslie gives, it is possible to eliminate many at once, and many others prove yet again the complete inability of untrained observers to describe what they are seeing. Again and again altitudes and speeds are given, despite the fact that these can seldom be estimated *even approximately* by a single observer. Such phrases as, for example "faster than a jet" are utterly meaningless, since a jet or its vapour trail (the undoubted explanation of many cases) can move across the sky at almost any apparent speed.

After reading this book a good dose of Dr. Menzel's *Flying Saucers* is strongly recommended as a purgative. In our opinion, Dr. Menzel goes too far to the other extreme, but he has done a useful service in showing what fantastic effects can be produced by perfectly natural causes. Such an attitude is far better (and healthier) than the naive credulity with which the book under review is permeated.

One example will suffice. A report is given of a saucer fleet over south-west France in October, 1952 (the date is important) which rained down "bright, whitish filaments like glass-wool." Many eye-witnesses gathered whole tufts, but unfortunately it disappeared before it could be taken to a laboratory.

From this report, Mr. Leslie conjures up a whole superstructure of speculation involving ectoplasm and celestial circuses. Anyone with an elementary acquaintance with natural history could have told him, on the other hand, that this beautiful phenomena happens every autumn over many parts of Europe; although this reviewer has only seen it once, he will never forget the sight of whole fields draped with a continuous carpet of glittering, almost invisible threads.

It did not occur to him that it was ectoplasm, which was a pity. How much more fun if he had never heard of the gossamer spider!

It would obviously be impossible to explain away all the sightings and phenomena reported by Mr. Leslie, and even if one did account for 99 per cent. of them, he would still cling desperately to the remaining hundredth. There is a type of mind which will believe anything if it is sufficiently fantastic, and it is a waste of time arguing with it. No one has ever received much thanks for exposing credulity.

The second part of this book consists of a report by one George Adamski, whose small observatory-cum-wayside café can be seen nestling at the foot of Mount Palomar, to the considerable annoyance of the people on the summit. Mr. Adamski's hobby is photographing flying saucers, and he is undoubtedly the most successful exponent of this interesting art.

There are several close-ups of saucer spaceships, leaving no doubt that they

are artifacts. The uncanny resemblance to electric-light fittings with table-tennis balls fixed underneath them has already been pointed out elsewhere. At first sight, indeed, one may almost conclude that Adamski's spaceship photos are so *un*convincing that they aren't faked. To us, the perspective appears all wrong, and though this is a qualitative impression perhaps not susceptible to rigorous proof, the pictures seem to be of a small object photographed from very close up and not a large object seen through a telescope. (Many people, including we suspect Mr. Adamski, do not realize that a large object seen through a telescope bringing it to within say 20 ft. looks quite different from the object itself 20 ft. away.)

We have a much more serious comment, however, to make on photograph 3, which purports to show a fleet of saucers taking off from the Moon. Alas, something has gone wrong here. We would like Mr. Adamski to account for the fact that one of the saucers appears to be *inside his telescope*.

This would not be apparent to anyone who was unacquainted with lunar geography, but an inspection of the background shows that the line of saucers is not clear of the Moon's edge—as appears at first sight—but extends *off the field of view of the lens* altogether. It is odd, to say the least, that Mr. Adamski's discriminating telescope is able to see a saucer and to ignore the Moon shining around it. . . .

There is one plate (No. 9) which is undoubtedly unfaked, and is an insult to the public. It is a night scene in New York, and shows a street lamp with a "saucer" hanging above it.

If Messrs. Adamski or Leslie had bothered to show this to any competent (or perhaps even better *incompetent*) photographer they could have learned at once that this was nothing more than the internal reflections in the camera lens ("flare") the almost inevitable result of having a bright light in the field of view. Even the characteristic curves due to spherical aberration are clearly visible, tangential, as they should be, to the line pointing to the source of light. The same camera, at the same place, will always produce the same saucer. If there is another edition of this deplorable book, at least the publishers should have the honesty to label this photograph for what it is.

But Mr. Adamski is not content merely to photograph saucers. With his friends, he succeeds in meeting the representative of saucerian civilization, when he lands his vehicle in the—presumably—totally uninhabited State of California. The account of this meeting should succeed in blasting any fragments of belief the more credulous readers may have in Mr. Adamski's reliability. It is as ludicrous as the idea that for years saucers have been flitting round Palomar—of all places !—invisible to everyone except Mr. Adamski and his friends.

This encounter with the Venusian pilot raises a very intriguing question. In his comprehensive account of saucer phenomena, Mr. Leslie makes no mention of the crashed spaceships described in Frank Scully's book *Behind the Flying Saucers*. (Though he does mention Scully in passing.) Can it be that there is something that Mr. Leslie does *not* believe in ? Or can it be because Mr. Scully's three-foot-high Venusians do not agree too well with Mr. Adamski's five-foot variety ? And what will he do when the seven-foot model turns up—as is only

a matter of time? I hope he will be sufficiently sporting not to ignore the rival versions as they accumulate.

We think that the above comments will be more than sufficient to enable any intelligent person to decide the merits of this book—and an entire volume of refutation would be wasted on the sauceromanes who are beyond the reach of reason. But we would like to end by saying why we are so annoyed with Messrs. Leslie and Adamski.

For a long time we were completely sceptical of saucers, and it was quite a shock to us when we discovered that they did exist and that for many of them no reasonable explanation (*pace* Dr. Menzel) has yet been forthcoming. Moreover, despite some serious objections (*see* our editorial in the May, 1953 *Journal*) the explanation that they are in fact the products of extra-terrestrial intelligences is stimulating, has small but definite probability, and should certainly not be dismissed with scorn—least of all by members of this society. But this conclusion is of such overwhelming importance that it cannot be accepted without a degree of proof that it would be unreasonable to demand in a case of lesser significance.

Books like *Flying Saucers Have Landed* do a real disservice by obscuring the truth and scaring away serious researchers from a field which may be of great importance. If flying saucers *do* turn out to be spaceships, Messrs. Leslie and Adamski will have done quite a lot to prevent people of intellectual integrity from accepting the fact. ARTHUR C. CLARKE.

Space Travel

(An Illustrated Survey of its Problems and Aspects. By Kenneth W. Gatland and Anthony M. Kunesch. 205 pp. Published by Allan Wingate, Ltd., London. 15s.)

In this book the problems of space travel are dealt with in a lucid and readable manner. Mathematics have been omitted entirely. The book is well illustrated with photographs and excellent drawings by J. W. Wood and R. A. Smith. In addition to the usual captions, explanations of the illustrations are given at the back of the book. A short but useful bibliography is also included.

The first third of the book is devoted to the history of the rocket; the remainder is devoted to the problems of space travel.

The physiological and psychological effects on the spaceship crew are dealt with, and the construction and operation of the spaceship is described. The orbital technique is given a chapter to itself, the military aspect of the satellite vehicle being put in proper perspective. This needed doing, in spite of the adverse effect it may have on progress of the interplanetary project. In Chapter 5 the effect of research and development in other fields is described and discussed, and various types of nuclear reactors and possible ion rockets are outlined. In Chapter 6, under the heading of "Operation in Space," possible vehicles for space flight are suggested. Mass ratio and its influence on characreristic velocity is defined. The chapter ends with a very credible description of "Operation Luna."

In the last chapter, "The Stars Beckon," the authors really let themselves

go, and give a picture of an interstellar Swiss Family Robinson setting out in a hollowed asteroid, on a journey of 400 to 500 years. One agrees with the authors that such a venture could be undertaken only at the highest cultural level.

Much of the matter of this book has been dealt with elsewhere and indeed it would be strange if this were not so. Perhaps too much importance has been given to the rocket motor, at the expense of the many other problems. Inaccuracies are few and mostly due to printing errors. The statement that the propellant (liquid oxygen and petrol) is fed to the Reaction Motor rocket by a hydrogen peroxide pump is objected to on purely personal grounds.

The layman, for whom it is obvious this book is written, may get the idea that interplanetary travel can start as soon as a suitable propulsion system is developed. It is true we know what sort of propulsion unit is required, how the spaceship should be constructed and which "flight plans" are the most economical, but there remains a host of less spectacular but equally important problems.

For example, the use of small jet pistols for personal propulsion is proposed. If the user does not align the thrust to pass through his centre of gravity, he will rotate; he will have no sensation of rotation apart from the slight centrifugal effect. It will appear to him that the universe is rotating about an axis passing through him, at an angle depending on the error he has made. The use of the jet pistol will be rather like riding a bicycle with three degrees of freedom.

Again, as the spaceship descends on the Moon, it is likely that a considerable amount of dust, and rock particles of various sizes will be thrown about. As the Moon has no appreciable atmosphere it is possible to orbit at any radius which clears the mountains. The velocity required would be of the order of 1 mile/sec., while the jet velocity would be of the order of 2 miles/sec. It is not inconceivable that some sizeable lumps of rock may acquire enough velocity to orbit the Moon. These fragments would come to a focus at their starting point about every 100 min. It would be disappointing if the spaceship, ascending from the Moon's surface, were to be, so to speak, consumed by its own smoke.

In the vehicle depicted it will be necessary to obtain full thrust immediately on starting the rocket motor, otherwise the legs may be burnt or battered, causing the ship to topple before it becomes jet-borne.

It is realized that such details could not be covered in the present book. May we hope that our astronautical authors will turn their attention to them in future books.

S. ALLEN.

Man in Space

(By Dr. Heinz Haber: Sidgwick & Jackson, Ltd., London, 291 pp. 30s. 1953.)

This book is primarily concerned with the problems involved in establishing an artificial satellite. The stresses to which the human organism would be subjected in shooting it to the necessary height and velocity, and the possible techniques for supplying it with the necessities of life, e.g. food, respirable atmosphere, gravity, etc., are discussed.

The problem is essentially one of size and therefore the economic factor is acute, for the project is linked to the mass of the human body and the necessary

ancillary paraphernalia. To imagine catapulting a small air-conditioned hotel into space will give some idea of the difficulties involved. But even apart from this, electromagnetic and mechanical devices are much more easily protected against the extraterrestrial environment than is the human organism. Also they are more flexible. The human eye, for example, is the most sensitive and exact of our exteroceptive sense organs, but it does not respond to infra-red or ultraviolet radiations—the latter destroy it ! It is not used to probe galaxies from Mount Palomar, so for a long time to come space will be explored by extending our senses by monitoring satellites—rocket eyes on radio stalks as it were.

This argument is conceded towards the end of the book, but the author feels that eventually man too, will enter the realms of space. Before reaching this point, however, a good deal of print is taken up by dwelling on what would happen to the human organism if deprived of oxygen or gravity, or if subjected to great accelerations, when, in fact, we expect that the human body will have an artificially created terrestrial environment to hand, and will not be sent unprotected into space.

The book is absorbingly written, and makes pleasant reading, the print being large and the pages relieved by numerous, but to the point, illustrations, and if the above parts had been more succinctly put, the price (which is rather high for a "popular" book of this nature), might have been reduced.

Dr. Haber is to be congratulated in presenting to the layman, an extremely difficult subject, in a very clear and interesting manner. C. R. ARMSTRONG.

Into Space

(By P. E. Cleator. George Allen & Unwin, Ltd., London. 159 pp. 15s.)

This book is described as "an interplanetary preview" on the dust jacket, but the reviewer would suggest that too much of the contents consist of an account of Mr. Cleator's brushes with British governmental establishments and offices: these are very interesting, but not really necessary to an understanding of the principles and techniques of space flight.

The remainder of the historical section in the book has already been covered at least as competently in Willy Ley's *Rockets, Missiles and Space Travel*.

In his description of rocket motors, which is not very comprehensive, the author makes the common error of describing a bi-propellant motor as a bi-fuel motor, and he goes on to dismiss the solid-propellant motor, if not with ridicule, at least with some disdain.

It seems appropriate to remark that it is very likely that first-stage boosters will be solid-propellant rockets, and that it is possible that current rocket development is directed more and more energetically to solid-propellant motors, as the multifarious complications of liquid propellant motors manifest themselves.

As regards the future, one may enquire whether a nuclear motor (using say, U235 with water or ammonia) or a lithium/liquid oxygen motor, are to be considered "solid" or "liquid" motors.

The author states (correctly) that the exhaust velocity in a typical hydrocarbon (gasoline)/liquid oxygen motor is about 7,000 ft. sec., and also points out that the theoretical exhaust velocity for this combination is some 14,000 ft./sec. This is true, but it does not follow that, in terms of exhaust velocity, the currently designed motors are only 50 per cent. efficient; the 7,000 ft.-sec. is achieved with a pressure ratio of about 20/1 and a nozzle area ratio of about 4/1. To get 14,000 ft./sec. we must have a pressure ratio of say 10^6/1 (which is easy in space !) and also a nozzle area ratio of about 20,000/1—which would present not the least difficult problems to the vehicle designer.

Such considerations as these make the "ion-gun" motor, with low thrust and extremely high specific impulse a much more attractive proposition at reasonable distance from attracting bodies. The author, has, unfortunately, confined his remarks to motors in which the exhaust velocity is achieved by expanding hot gases through nozzles.

The author has illustrated his work quite well with plates from Mount Palomar Observatory, "Destination Moon," etc., and the line illustrations include some of Giles' work from the *Daily Express*.

By and large, this book is not regarded as the best introduction to spaceflight; there are too many sidetracks and some errors. One of the most unforgivable of these is made three times—Sir Frank Whittle's company which did so much early work on gas turbines is wrongly described as *Pioneer* Jets, Ltd.

E. T. B. SMITH.

Man on the Moon

(Edited by Cornelius Ryan. 134 pp., 15 illustrations, 12 in colour. Published by Sidgwick & Jackson, Ltd., London. 25s.)

In this book, which continues the series *"The Conquest of Space"* and *"Across the Space Frontier,"* the authors present a detailed analysis of what they conceive will be the first Lunar expedition of 50 men, who travel from an orbit round the Earth to the Moon surface and return after a stay of six weeks. The journey is made in three rocket vehicles, one of which is abandoned on the lunar surface. These moon-ships are built and fuelled over a period of eight months in the earth orbit. A fleet of three-step ferry rockets bring the material up from the Earth.

It is stated explicitly in the first page of Chapter 1 that by the time the expedition is a reality there will be better solutions to the technical problems. "The purpose of the book is to show that a lunar voyage is possible even now by applying the engineering knowledge and technical ability available to us to-day." If the book succeeds in this objective it also makes it plain that there is no margin between success and failure. The authors increase their difficulties by the grandiose nature of their scheme. On their own admission they are trying to operate the equivalent of a trans-atlantic service with the Wright brothers' first machine.

Considering some points of detail, it is not clear why the moon-ships are assembled in the same orbit as the space-station. No use is made of this structure, and a rapidly precessing orbit has its disadvantages.

The mass of ships and fuel is worked out with unwarranted precision. A change of only 10 per cent. in the exhaust velocity introduces a factor of almost two in the starting up weight from the orbit, and a factor of five on the total fuel bill (for 2,200,000 tons). Unless the authors are letting out some top secrets the exhaust velocity used is not a proved performance figure, but only a reasonable estimate of what may be achieved. The author's plan to move the expedition base into a fissure immediately upon landing, but we may show by a *reductio ad absurdum* that this will not be necessary. The meteor and cosmic-ray hazards will be of similar intensity on the surface of the Moon and in the chosen orbit (which passes nearly over the magnetic pole) and although the ships are on the Moon for six weeks they are in the orbit no less than 32 weeks.

The flat floors of the base huts are subject to a pressure differential of 8 lb. per sq. in., involving a considerable structural weight penalty which could be avoided by retaining the cylindrical form.

As the authors remark, few of those who have written about lunar trips know what to do when they get there. Chapters 7 and 8 present a comprehensive programme of investigations, and a fascinating account of the varied scientific techniques which might be employed.

The book appears largely free from minor errors and misprints, but we may note:—

On p. 36 appears the caption for an illustration on p. 38.

On p. 129 the inclination of the Moon's equator to its orbit should be around 6°30′. The figure given is the inclination to the ecliptic.

On p. 133 the mass ratio for the final manoeuvre is not quite enough to produce the quoted velocity change. The men would have to leave their personal luggage on the Moon, thus maintaining the tradition in these voyages.

The illustrations maintain the quality of the series, and the book as a whole is a stimulating exposition of the possibilities of the future. C. A. Cross.

A Guide to the Moon

(By Patrick Moore. Published by Eyre & Spottiswoode, Ltd., London. 255 pp. with 12 plates and 11 figs. 1953. 16s. 0d.)

This book gives a clear and very interesting account of the Earth's only satellite, its surface conditions, its past, present, and future, as envisaged by various astronomers. The lunar phenomena are treated fully and in such a manner that only the most unimaginative reader can fail to picture the craters with their massive walls, the extremes of light and shadow, the lofty mountain chains and the mysterious ray systems.

An important feature of the book is the set of appendices. The first contains some good advice to the reader who wishes to observe the Moon telescopically. The second is a list of lunar literature and lunar maps. The third gives a list of future lunar eclipses from 1953 to 1987, with times of mid-eclipse, type of eclipse and whether visible in America and/or England. The fourth appendix, a very useful one for amateur observers, contains descriptions of over 200 of the main lunar features.

The vexed question of the observation of meteor trials and impacts upon

the Moon is discussed. In this connection the evidence for the existence of a tenuous lunar atmosphere is marshalled. It is pointed out that although at surface-level the density of the lunar atmosphere is certainly a very small fraction of the Earth's (at most 1/10,000), at a height of fifty miles the density may be equal to or indeed greater than the Earth's at a similar level. Thus the atmosphere of the Moon should be just as effective a meteor shield as ours, a matter of some satisfaction to the occupants of a lunar colony.

Some space is given to discussions of changes observed on the lunar surface. The evidence for mists seen inside craters from time to time is good. For example, surface features are occasionally obscured by fog. These are temporary changes. There have been one or two permanent changes, according to some observers, and the author discusses, among others, the famous case of Linné, on the Mare Serinitatis.

Two chapters are devoted to an elementary outline of space-travel to the Moon. The first of these touches upon the problems of getting there; the second considers the problem of maintaining a colony there.

Mr. Moore's book should be read with enjoyment and profit by all those interested in our planet's satellite. It should be the means of encouraging more amateurs to take an active interest in observing the Moon. For the Moon, in these days of the big telescopes, is the domain of the amateur and it is to Mr. Moore and his colleagues that credit is due for showing us that the statement that "the Moon is a dead, airless world" is only approximately true.

A. E. Roy

The Adventure of Space Travel

(By G. V. E. Thompson. Dennis Dobson, Ltd. 253 pp. 10s. 6d. net.)

This book is designed for readers of all ages without scientific or mathematical knowledge or a wide vocabulary (even the word "fabricate" is followed by an explanation in brackets!) The layout is well conceived, the subject matter comprehensive and the text well written. Sensational and over-optimistic schemes are avoided and the author maintains throughout the book a sober and proverbial "down to earth" realism.

When a second edition is contemplated, it might be useful to add appendices containing tabulated information, about the Sun, planets and satellites and some of the elementary and basic formulae and graphs dealing with the Dynamics of Space Flight. Hidden at the back of the book they would not scare the general reader and would give thousands of small boys and girls a new interest in, and a new reason for, their mathematical studies.

The sketches and diagrams in the book are very good and well serve their purpose; the illustrations by R. A. Smith are magnificent. One photograph shows a giant centrifuge in the U.S.A., probably to illustrate the principle of artificial gravity for space stations. Another, of the Douglas Skyrocket leaving its mother 'plane, illustrates a present-day application of the step-rocket principle. A photograph of aircraft flight refuelling by drogue and probe might have made good company for R. A. Smith's illustration depicting orbital refuelling. A portrait of the world's first monkey to return from a flight into

space would have been more popular than the two photographs devoted to its fellow-travellers, two white mice. The world's first operational rocket fighter is also not illustrated, for the general public does not remember that it saw action in 1944, and still considers it as a futuristic project. It is a pity that what must be a questionable map of Mercury was included instead of a more respectable chart of Mars.

It is very agreeable to note that the author regards our Moon as the Earth's twin planet rather than its satellite and thus overcomes the last remnant of the Ptolemaic cosmology. It is a pity though, that Baldwin's or even Nininger's meteoric theses on the prime cause of all major lunar features (which neither preclude minor nor secondary forms of vulcanism), are not (to your reviewer) given a fairer hearing.

O. W. NEUMARK.

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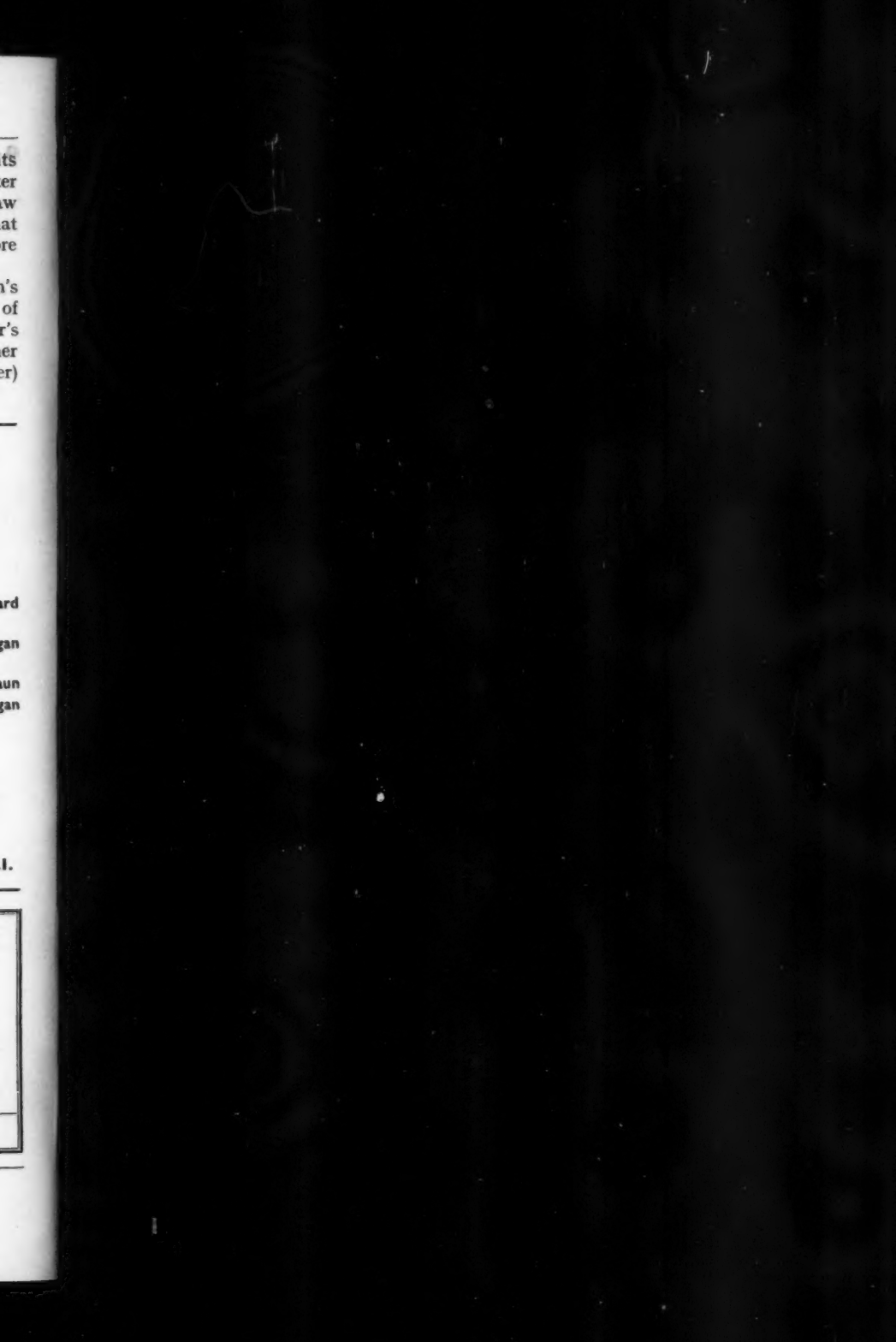
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